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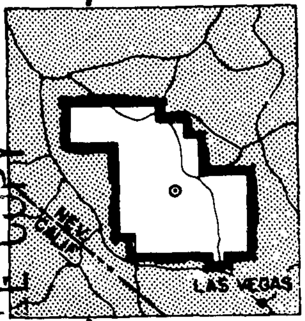

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MAY-OCTOBER 1957

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Project 2.10

INITIAL NEUTRON and GAMMA AIR-EARTH INTERFACE MEASUREMENTS (U)

Issuance Date: February 23, 1960

HEADQUARTERS FIELD COMMAND
DEFENSE ATOMIC SUPPORT AGENCY
SANDIA BASE, ALBUQUERQUE, NEW MEXICO

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(21) Report on OPERATION PLUMBBOB—PROJECT 2.10

(6) INITIAL NEUTRON and GAMMA AIR-EARTH INTERFACE MEASUREMENTS [redacted],

(11) 23 Jan 60,

(12) 70 p.

(10) by

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ABSTRACT

Measurements of total gamma dose, gamma dose rate, neutron flux, and neutron dose were made at the surface and at heights up to 950 feet to determine the effect of the air-ground interface on initial nuclear radiation. Measurements of total gamma dose and neutron flux were made with dosimeters fastened to towers 500 feet high and to the mooring cables of captive balloons 950 feet high. Total gamma measurements were made with three types of film badges, two types of phosphate glass dosimeters, quartz-fiber dosimeters, and chemical dosimeters. Neutron-flux measurements were made with sulfur pellets and with nuclear track emulsions. Neutron-dose measurements were made with chemical dosimeters. Measurements of gamma dose rate were made with air-filled, saturated, ion-chamber detectors carried by captive balloons with signals carried by miniature coaxial cable to ground stations and recorded on magnetic tape.

It was found that total gamma dose increased with height to a value, at 400 feet, 30 percent greater than ground measurements. There was no further increase up to 950 feet. The effect was the same at all stations from 1,500 to 3,500 yards horizontal distance from burst point. There was no change in the ratio of gamma dose rates at the balloon stations compared to dose rates at ground stations over the first 5-second interval for which records were obtained.

Sulfur neutron-flux measurements increased with height to a value of 30 percent greater than ground measurements at 500 feet. No change was observed from 500 feet to 950 feet. Neutron rep-dose measurements were not conclusive.

FOREWORD

This report presents the final results of one of the 46 projects comprising the military-effect program of Operation Plumbbob, which included 24 test detonations at the Nevada Test Site in 1957.

For overall Plumbbob military-effects information, the reader is referred to the "Summary Report of the Director, DOD Test Group (Programs 1–9)," ITR–1445, which includes: (1) a description of each detonation, including yield, zero-point location and environment, type of device, ambient atmospheric conditions, etc.; (2) a discussion of project results; (3) a summary of the objectives and results of each project; and (4) a listing of project reports for the military-effect program.

PREFACE

The authors wish to express their appreciation to the many persons who have aided them during the course of this project. They want to thank Clarence Slover, of the Lexington Signal Depot, who supplied and processed the LSD stack film dosimeter; Fred Riggin, of the New York Naval Shipyard, who furnished and read the glass needle dosimeters; Walter Cordek, of Sandia Corporation, for his assistance with balloon operations; Dave Rigotti and John Kinch of Army Chemical Center, Maryland, for their assistance in neutron dosimetry; and Gerald Carp and Ross Larrick, of the Evans Signal Laboratory, for assistance and counsel throughout the entire project.

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Chapter I
INTRODUCTION

1.1 OBJECTIVE

The objective of this project was to determine the effect of the air-ground interface on measurements of integrated gamma dose, initial gamma dose rate versus time, and neutron flux on the ground as compared to measurements taken in free air. This objective was accomplished by measuring the integrated gamma dose and neutron flux at points on the ground and at corresponding points in the air at heights up to approximately 950 feet and by measuring the gamma dose rates during the initial 10 seconds at points on the ground and at corresponding points approximately 950 feet above the ground. Tethered balloons were used to carry the gamma-dose-rate equipment and other instruments. Measurements of integrated gamma dose and neutron flux were made at intervals along the balloon mooring cables.

1.2 BACKGROUND

The Air Force has a vital interest in knowing the gamma and neutron doses from nuclear weapons burst at high altitudes. In some cases the nuclear radiation dose received by the crew of the delivery aircraft seriously limits the operational capability of the aircraft. Predictions of dosage must be as accurate as possible in order to permit the maximum operational capability of an aircraft delivering nuclear weapons without exposing the crew to excessive radiation dosage.

With the exception of the high-altitude (HA) shot of Operation Teapot (References 1 and 2) field measurements of initial nuclear radiation have been made only near the surface. On the Teapot HA shot, there were discrepancies between doses predicted on the basis of previous ground measurements and the doses actually observed. The gamma dose measurements were about 50 percent higher than gamma dose measurements taken at the surface for the correlation shot (Wasp Prime). Neutron flux measurements for the HA shot varied with distance, being equal to or slightly lower than surface measurements for the correlation shot at close distances and as much as 75 percent higher at some of the distant stations.

One of the factors contributing to this discrepancy may be the effect of the air-ground interface. The limited amount of information available concerning the possible effects of air-ground interface indicated that the ground acts as a sink for gamma radiation so that gamma measurements taken near the surface may be low as compared to free-air measurements at the same distance. No information was available concerning the possible effect of the air-ground interface on neutron flux.

It was believed that other factors, such as source-size corrections and cloud rise corrections, also influenced the Teapot HA measurements. It was not clear, however, how much of the discrepancies between the HA measurements and surface measurements were caused by the ground surface and how much by the other factors. Therefore, it was necessary to determine the effects of the air-ground interface in order to extrapolate ground measurements to high altitudes with sufficient accuracy to fulfill Air Force operational needs.

1.3 THEORY

It has been recognized for some time that the presence of the ground surface may significantly affect the radiation dose from a nuclear detonation for a receiver on or near the ground. The Capabilities of Atomic Weapons Manual (Reference 3) states that the gamma dose should be multiplied by 1.5 for receivers well above the ground surface. A hand calculation scheme (Reference 4) used at the Air Force Special Weapons Center (AFSWC) indicates that the effect of the air-ground interface on gamma dosage varies with distance. The effect increases with distance from negligible amounts at close distances to a factor of two at the distance where a radiation dose of about 25 r would be received from a 1 kt detonation and may exceed a factor of two at larger distances.

Recent Monte Carlo calculations by the National Bureau of Standards (NBS) show that for a Co^{60} source, the effect of the air-ground interface on dosage varies with distance from the source and with height above the surface. These calculations have been verified experimentally using a steel-wool-over-steel medium to simulate the air-ground interface (Reference 5). At a distance of four mean free paths, the calculated dose at the surface was about half the dose for the free-air case. The effect of the interface decreased with height. At heights of one mean free path or above, the effect was negligible, so that the receiver was essentially under free-air conditions.

A laboratory experimental program to measure the effect of an air-water interface on the dose from several different source energies was recently completed (Reference 13). Results indicated the effect of the interface varied with distance from the source and was confined to a region near the surface. These results, coupled with the NBS results, led to the conclusion that at heights of about 1,000 feet or more above the surface at field tests a detector would essentially be under free-air conditions and would not be influenced by the ground surface. This would permit a direct comparison of measurements taken at the surface and under free-air conditions 1,000 feet above the surface. Such measurements would be sufficient to determine the effects of the air-ground interface on initial nuclear radiation from nuclear devices.

From an analysis of the above theoretical studies and experimental programs, it was apparent that the effect of the ground surface was to reduce the amount of scattered radiation reaching the receiver. As distance from the source increased, the amount of scattered radiation reaching a receiver increased in comparison to the unscattered or direct radiation. At great distances the dose from the scattered radiation could equal or exceed that from the direct radiation. This increase in dose caused by scattered radiation has been called the dose-build-up factor (Reference 6). In effect, the ground surface reduced the build-up factor and therefore reduced the dosage. The direct or unscattered radiation was not affected by the interface.

As far as could be determined, no theoretical analysis of the effect of the air-ground interface on neutron flux had been made. Also, because of the difficulties of simulating the neutron-scattering properties of air and soil in a compressed system, it had not been possible to devise a laboratory experiment to obtain measurements. Since there was no theoretical or experimental evidence available, the selection of the height above the surface for the neutron detectors was somewhat of a guess. By assuming that any effect of the air-ground interface on neutrons would be comparable to the expected effect on gamma radiation, it was possible to infer that the height of the balloons used for gamma measurements would also be sufficient for neutron measurements. The effect on gamma radiation was expected to be confined to a region within one mean free path of the surface. The balloon height of 950 feet was about one mean free path for gamma radiation. Neutrons have a mean free path of about 650 feet, so the balloon height was more than one mean free path above the surface for neutrons. Therefore, it was felt that measurements taken along the balloon mooring cables would cover the region from ground conditions to free-air conditions for neutrons.

In selecting horizontal distances, the only guide available was the belief that any effect of the air-ground interface was expected to increase with distance. For this reason, it was desirable to take measurements as far from the burst point as possible in order to have the greatest possible difference between ground and free-air measurements. The array of four balloons was therefore placed at the greatest distance at which reliable measurements could be obtained. A

minimum of approximately 50 rep calculated for neutron dose was used to determine the closest station and a minimum of approximately 0.5 r calculated for gamma dose was used to determine the farthest station. The balloons were then placed at the Project 2.5c ground stations that most nearly met these criteria.

Chapter 2
PROCEDURE

2.1 SHOT PARTICIPATION

Primary participation was on Shots Lassen, Wilson, Hood, and Owens. These shots were selected to coincide with Project 2.5c participation. Operational activities included instrumenting and launching four separate ballons the day before each of the shots listed. The balloons were filled with helium and launched as late as practical the day preceding a shot in order to avoid the gusty wind conditions during the day and to take advantage of the calmer winds during the late afternoon or night. The balloons were supplied and handled by the General Mills Company, Minneapolis, Minnesota, under contract to AFSWC. The balloons were located at distances of 1,000 yards to 3,580 yards from ground zero.

In addition to the above, towers within appropriate ranges of Shots Boltzmann, Diablo, and Kepler were instrumented with total gamma dosimeters at intervals of 50 feet from the ground to the top of the tower. For Shot John, one balloon carrying total gamma dosimeters was moored 5,000 feet above ground zero.

2.2 INSTRUMENTATION

2.2.1 Total Gamma Dose. Total initial gamma dose was measured using National Bureau of Standard (NBS) film badges, Lexington Signal Depot (LSD) stacked film dosimeters, unshielded film packets, quartz-fiber dosimeters, DT-60 phosphate-glass dosimeters, glass-needle phosphate-glass dosimeters, and USAF School of Aviation Medicine (AFSAM) chemical dosimeters.

The NBS film badge holder consisted of a dental-size film packet inside a bakelite shield (specific gravity 1.4 grams/cc) with walls 8.25 mm thick. The bakelite was covered by 1.07 mm of tin and 0.3 mm of lead (Reference 7). The badge holder was made in two sections for ease of film removal. A strip of lead 1 mm thick was wrapped around the edges to prevent stray radiation entering along the seam where the two sections join. The assembled film badge was placed in a plastic container for weather protection.

The LSD stack film dosimeter was an experimental dosimeter designed by U.S. Army Lexington Signal Depot for low-range personnel monitoring. The dosimeter consisted of a bekelite container with walls 4 mm thick. Three film packets were placed in each container. The center packet was covered with a shield of 1.07 mm tin and 0.3 mm lead. The two unshielded packets were placed on each side of the lead shield. To determine dosage, the film density was read through the three pieces of developed film stacked together. The film types used were Dupont 510 for the center film and Dupont 606 for the two side films. The energy response had been checked for a wide range of X-rays and gamma-radiation energies and found to be independent of energy.

The unshielded film packets were simply packets of dosimeter film similar to Rad-Safe film badges. The quartz-fiber dosimeters were Victoreen Model 541/A and Bendix Models 611, 622, 619, 686, and 803.

The DT-60 phosphate-glass dosimeters were the DT-60/PD personnel dosimeters. The responsive element was a section of phosphate glass 18 mm square and 5 mm thick. This element was carried in a bakelite case with walls 1.5 mm thick and with a 1-mm lead shield on each side of the glass. The glass-needle phosphate-glass dosimeters were small glass needles encased in a lead shield with walls 1 mm thick. After exposure to gamma radiation the response of phosphate glass dosimeters was indicated by an increase in fluorescense upon illumination by ultraviolet light (Reference 8).

The chemical dosimeters were 1 cc vials of tetrachloroethylene. The vials were placed in a lucite block $\frac{1}{2}$ inch thick. The lucite block was covered with a lead shield $\frac{1}{2}$ mm thick. Gamma radiation liberated acid from the tetrachloroethylene and the resultant change in pH was measured to determine the gamma exposure (Reference 9). The change in pH was measured by changes in the optical transmission of the indicator dye in the vials.

From two to four types of dosimeters were used at each station. The instrument stations were located at heights of 0, 3, 10, 30, 50, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900 and 950 feet above the ground along the balloon mooring cables. The balloons were General Mills aerocaps approximately 31 feet long and 11 feet in diameter. Each balloon was flown from a single mooring cable. The aerodynamic shape of the balloon provided a high lift-to-drag ratio so as to keep the balloon nearly vertical above the ground anchor under varying wind conditions.

Dosimeters were wrapped in styrofoam to protect them from shock when they fell after the balloon was destroyed by the thermal radiation and blast. The styrofoam in turn was wrapped with aluminum foil for thermal protection. The dosimeter packages were fastened to the balloon mooring cable with wire and masking tape.

2.2.2 Neutron Measurements. Neutron-flux measurements were made by using sulfur pellets and nuclear track emulsions as detectors. A few measurements were also made using fission-foil detectors. Neutron-dose measurements were made using AFSAM chemical dosimeters.

The sulfur pellets were molded pellets $1\frac{1}{2}$ inches in diameter and about $\frac{3}{8}$ inch thick. The fission-foil detectors were foils of U^{238}, and Pu^{239} incased in a spherical boron shield 1 cm or 2 cm in thickness (Reference 10).

Nuclear-track emulsions were photographic emulsions especially prepared to show proton recoil tracks. The emulsions used were Kodak personal neutron monitoring film Type B. Neutrons above an energy of approximately 0.3 Mev produce proton recoils from the hydrocarbon in the emulsion. The proton recoils leave dense tracks, which are counted under a microscope (Reference 11).

The chemical dosimeters were 1-cc vials of tetrachloroethylene and water. This dosimeter was sensitive to both neutron and gamma radiation. The tetrachloroethylene gamma dosimeter was insensitive to neutron radiation. The neutron dose was obtained by subtracting the gamma dose determined with tetrachloroethylene dosimeters from the gamma plus neutron dose determined with the tetrachloroethylene-and-water dosimeters.

The neutron detectors were packaged in the same manner as the gamma dosimeters and placed at the same locations on the balloon mooring cables. On Shot Owens an additional number of sulfur pellets were placed from 0 to 50 feet above the surface at distances of 1,000 and 1,500 yards from ground zero. Fission-foil detectors were placed at the ground and at the 950-foot height for Shots Lassen and Hood. Table 2.1 lists the shot participation and location of the various types of gamma and neutron dosimeters.

2.2.3 Gamma Rate Measurements. Gamma dose rate as a function of time was measured by the use of saturated ion chambers carried aloft by balloons. The ion chambers and all associated electronic gear were designed and built by Evans Signal Laboratory personnel in conjunction with Operation Plumbbob Project 2.5c. The ion chambers were air filled and kept at a potential above the saturation potential and well below the Geiger region potential. The ionization current through the chamber bled into a capacitor, which provided bias potential for a multivibrator circuit. The multivibrator circuit recharged the capacitor, which then cut off the oscillation. The result was a single oscillation of the multivibrator circuit for a fixed current flow through the ion chamber. This, in turn, corresponded to a fixed dosage received by the ion chamber. The frequency of pulses was thus a direct measure of the dose rate.

Pulses from the multivibrator circuits were used to key an 8-, 10-, or 12-Mc transmitter so that signals from three ion chambers could be transmitted simultaneously along the same line. These signals were transmitted from the balloon to the ground recording station along miniature coaxial cable (RG 174/U). The entire system was shielded in order to reduce signals from the electromagnetic pulse as much as possible. At the ground station the carrier-frequency pulses

TABLE 2.1 SHOT PARTICIPATION AND LOCATION OF TOTAL GAMMA AND NEUTRON DOSIMETERS

Shot	Horizontal Distance from Ground Zero	Vertical Heights*	NBS Film Badge	LSD Film Badge	Unshielded Film Packet	Quartz Fiber Dosimeter	DT-60	Glass Needle	Chemical Dosimeter, Gamma	Sulfur Pellets	Nuclear Track Film	Fission Foils	Gold Foil	Chemical Dosimeter, Neutron
	ft	ft												
Boltzmann	17,100	0-300T	•	•	•									
Lassen	3,000	0-950B					•		•	•		•	•	•
	4,500	0-950B			•									
	6,000	0-950B									•			
	7,500	0-950B		•										
Wilson	4,500	0-950B	•			•	•		•	•				•
	6,000	0-950B	•		•	•	•							
	7,500	0-950B	•	•	•									
	9,120	0-950B	•	•							•			
Hood	6,000	0-950B	•		•		•	•	•	•		•	•	•
	7,500	0-950B	•		•	•	•	•		•				
	9,120	0-950B	•	•	•	•	•				•			
	10,740	0-950B	•	•	•									
Owens	3,000	0-50B								•				
	4,500	0-50B								•				
	4,500	0-950B	•	•	•		•	•	•	•				•
	6,000	0-950B	•	•	•	•	•			•				
	7,500	0-950B	•	•	•	•					•			
	9,120	0-950B	•	•	•	•								
Diablo	5,010	0-500T	•			•	•		•	•		•	•	•
	8,145	0-500T	•			•					•			
Kepler	11,850	0-500T	•	•										
John	0	5,000 B	•	•										

*T, tower; B, balloon.

were separated, demodulated, and then recorded as pulses on a multichannel magnetic-tape recorder. At the same time, pulses from similar ion chambers mounted at the ground station were recorded on other channels on the magnetic tape. Thus, a direct comparison between dose rate at the ground station and 950 feet above the station was obtained.

A total of 14 balloon-borne gamma-rate stations were employed. Four were used during each of Shots Lassen, Hood, and Owens and two during Shot Wilson. The electronic components and battery power supplies were made as light in weight as possible, in order to reduce the load carried by the balloon. The complete gamma rate station with coaxial cable weighed about 20 pounds. For a complete description of the airborne gamma-rate instruments and the corresponding ground installations, see the Project 2.5c report (Reference 12).

2.3 DESCRIPTION OF REQUIRED DATA

2.3.1 Data Required. The data required included: neutron flux and dose as a function of slant range from the detonation and height above the ground surface, total gamma dose as a function of slant range from the detonation and height above the ground surface, and gamma dose rate as a function of time and slant range for approximately 10 seconds at the ground and at heights of 950 feet above ground.

2.3.2 Methods of Recording. Neutron flux was recorded by activation of sulfur pellets, gold foil, fission foils, and by proton recoils in nuclear track emulsions. Neutron dose was recorded by chemical dosimeters. Total gamma dose was recorded by its effect on film badges, chemical dosimeters, phosphate-glass dosimeters, and quartz-fiber dosimeters. Gamma dose rate was detected by saturated ion chambers and recorded on magnetic tape.

2.3.3 Data Reduction. NBS film badges and unshielded film packets were processed and read by Evans Signal Laboratory, Project 2.5c. LSD film badges were processed and read by Clarence Slover of Lexington Signal Depot. Chemical dosimeters were read by Project 39.1 Civil Effects Test Group. Sulfur, gold and fission foil detectors were counted by the Army Chemical Warfare Laboratory, Project 2.3. Glass-needle dosimeters were read by Navy Bureau of Ships, Project 2.8. Nuclear-track films were read by Cook Electric Co. under contract to AFSWC. Quartz-fiber dosimeters were read visually and DT-60 dosimeters were read on a CP-95/PD reader. Magnetic tapes were transposed onto 35-mm film, which was processed by Edgerton, Germeshausen and Grier, Inc. The films were read by Project 2.5c and 2.10 personnel.

2.3.4 Additional Support. Technical photography, consisting of phototheodolite records and 16-mm Gun Sight Aiming Point (GSAP) records, was provided by Program 9 for the purpose of determining balloon positioning. The balloons were moored by a single cable and so were subject to displacement by winds from the intended location. Camera triangulation using bomb-light illumination was required to determine the actual balloon location at shot time.

Routine meteorological information was required in order to determine the air density as a function of altitude at shot time. Air density was needed so that all measurements could be corrected for variations in attenuation. Detailed surface wind predictions for the 24 hours preceding each shot were required in order to plan the balloon inflation and launching procedures.

Helium for balloon inflations was supplied by Lakehurst Naval Air Station, Project 5.2.

On Shot Owens, natural-shaped balloons furnished by Sandia Corporation were used after the available supply of aerocap balloons was exhausted.

Chapter 3
RESULTS

3.1 GENERAL OPERATIONAL RESULTS

3.1.1 Shot Boltzmann. For this shot NBS film badges and LSD film badges were fastened to the cross members of the Shot Franklin tower. All the film badges were recovered after the shot. The exposures were near the lower limit of sensitivity of the film badges (about 0.1 r) but were believed to be valid readings.

3.1.2 Shot Lassen. Four balloons were launched on D - 1 for this event. The balloons were located at 1,000, 1,500, 2,000, and 2,500 yards from ground zero. All balloons were in position at shot time; however, the yield was too low to give any measurable reading. All four balloons survived the shot and three were successfully recovered. The fourth balloon was lost because of high winds during the night of D + 1.

3.1.3 Shot Wilson. Four balloons were launched at distances of 1,500, 2,000, 2,500, and 3,040 yards from ground zero on D - 1. The balloon at 2,500 yards apparently leaked and came down, since it was missing at shot time. Total gamma dose and neutron flux measurements were obtained from the dosimeter packages along the three remaining balloon mooring cables. Only two balloon-borne gamma rate stations were employed for this shot. These were carried by the 2,500 yard and 3,040 yard balloons. The 2,500 yard station was lost before shot time when the balloon fell. The 3,040 yard ground station did not operate because of a faulty switch, so no rate information was recorded. The three balloons in position were destroyed by the shot. The farthest balloon (3,040 yards) was observed descending towards the ground at approximately H + 10 seconds.

3.1.4 Shot Hood. For this shot four balloons were launched at distances of 2,000, 2,500, 3,040 and 3,580 yards from ground zero. All balloons were in position at shot time and all were destroyed by the blast and thermal effects from the shot. Total gamma dose and neutron-flux measurements were obtained from the dosimeter package on the mooring cables. Gamma-rate information was obtained from three stations. The gamma-rate signal from the other station was obscured by random noise signals.

3.1.5 Shot Diablo. Total-gamma dosimeters were fastened to cross members of the Shot Whitney and Shot Shasta towers. Sulfur pellets and gold and fission-foil detectors were placed on the Shot Whitney tower. Total-gamma measurements were obtained from both towers, but the neutron flux was too low to activate any of the detectors except the gold foils.

3.1.6 Shot Kepler. Total-gamma dosimeters were placed on the Shot Shasta tower for this shot. The gamma dosage was too low to measure, however, so no readings were obtained.

3.1.7 Shot John. Total-gamma dosimeters were carried by a balloon moored at 5,000 feet over ground zero. The balloon was in position at shot time, but the dosimeters were not recovered. It is believed that the dosimeters were lost a few minutes after shot time when the mooring line broke because of excessive wind loading on the balloon. For this shot a light nylon rope of 800-pound tensile strength was substituted for the usual 1,200 pound tensile-strength steel cable, because the weight of 5,000 feet of steel cable was more than the balloon could lift. The

recoil of the nylon after breaking was apparently sufficient to break the fastenings holding the dosimeters to the nylon rope, since the dosimeters were not found when the rope and balloon were recovered. This problem was not encountered with dosimeters fastened to the steel mooring cables. Of a total of nearly 300 dosimeter packages used on steel cables, only two were not recovered.

3.1.8 Shot Owens. Four balloons at distances of 1,500, 2,000, 2,500, and 3,040 yards from ground zero were launched on D - 1 for this event. All balloons were in position at shot time and all total gamma dosimeters and neutron detectors were recovered. Two gamma-rate measurements were obtained. The other two stations were again obscured by random noise signals.

For this shot, 23-foot-diameter natural-shaped balloons were used instead of the aerocaps. This change was necessitated by the loss of all remaining aerocaps by high winds following several shot postponements. Since the winds were calm on the night of D - 1 and at shot time, the natural-shaped balloons performed satisfactorily. At the 1,000 and 1,500 yard stations, a number of sulfur pellets were placed at heights up to 50 feet to investigate more closely the effect of neutron flux near the surface. The pellets at the 1,000-yard station were held aloft by a cluster of meteorological balloons.

After the shot, two balloons were observed as they descended. The 2,500-yard balloon reached the ground at approximately H + 60 seconds, and the 3,040-yard balloon was down by approximately H + 80 seconds.

3.2 TOTAL-GAMMA DOSE

Measurements of total-gamma dose were obtained at heights from 0 to 950 feet on 11 balloon mooring cables and at heights from 0 to 500 feet on three towers. The measurements at the elevated stations were corrected for slant range and air density [I_0 (calculated)] and compared to measurements taken at the ground [I_0 (measured)]. The average of the measurements at 0, 3, and 10 yards was selected as the ground measurements for this comparison. Table 3.1 lists the relative value for all gamma measurements as a function of height above the surface.

Table 3.2 lists the relative values as a function of height for each distance at which a number of measurements were taken. Table 3.3 lists the relative values as a function of height for all dosimeter types used at all distances for each shot. Table 3.4 lists the relative values as a function of height for each dosimeter type used. All the measurements obtained are listed in Appendix A.

The relative gamma measurements as a function of height for all shots and each station distance are shown graphically in Figures 3.1 through 3.8. Figures 3.9 to 3.13 show relative gamma measurements for all dosimeters at all distances for each shot. Figure 3.14 is a composite of all gamma measurements.

3.3 NEUTRON-FLUX MEASUREMENTS

Neutron-flux measurements from 0 to 950 feet above the surface were obtained for Shots Wilson, Hood, and Owens. These measurements were obtained with sulfur pellets, nuclear track emulsions, and chemical dosimeters. During Shot Owens additional measurements with sulfur pellets from 0 to 50 feet were made for two distances; during Shot Diablo a set of measurements with nuclear track emulsions were obtained on the Shot Shasta tower.

The sulfur flux measurements are listed in Table 3.5A and shown in Figure 3.15. The data in Table 3.5B is not presented graphically since the variation in the first 50 feet was inconclusive. Neutron flux measurements made with nuclear track film are listed in Table 3.6 and shown in Figure 3.16. The measurements made with chemical dosimeters are listed in Table 3.7 and shown in Figure 3.17. Table 3.8 lists the flux data obtained with gold foil and fission-foil detectors during Shot Hood and with gold foil during Shot Diablo.

3.4 GAMMA RATE MEASUREMENTS

Useful records of gamma rate were obtained on 5 out of 14 stations in place at shot time. Three of these records were obtained during Shot Hood and two during Shot Owens. The results are shown in Figures 3.18 through 3.22. In each case, the gamma dose rates from the balloon-

TABLE 3.1 AVERAGE RELATIVE GAMMA DOSE AS A FUNCTION OF HEIGHT, ALL SHOTS, ALL STATIONS, ALL DOSIMETERS

Height	Relative Gamma Dose	Number of Measurements	Average * Deviation
ft			
Ground	1.000	—	—
0	1.004	24	± 0.054
3	.996	38	± 0.044
10	1.013	24	± 0.056
30	1.073	31	± 0.106
50	1.043	32	± 0.088
100	1.087	34	± 0.102
150	1.189	34	± 0.149
200	1.140	36	± 0.134
250	1.160	28	± 0.119
300	1.184	29	± 0.178
400	1.222	30	± 0.145
500	1.237	32	± 0.218
600	1.275	22	± 0.249
700	1.242	26	± 0.187
800	1.317	26	± 0.225
900	1.367	16	± 0.260
950	1.293	19	± 0.175

* The deviation listed is the average of the individual deviations from the mean.

TABLE 3.2 RELATIVE GAMMA MEASUREMENTS AT FIVE DISTANCES FROM GROUND ZERO, FOR ALL INSTRUMENT TYPES

Height	Distance from Ground Zero				
	1,500	2,000	2,500	3,040	3,580
ft	yd	yd	yd	yd	yd
0	0.916	1.042	1.015	1.012	0.995
3	0.931	1.014	0.963	0.989	1.009
10	1.099	0.985	1.025	0.998	0.993
30	1.049	1.056	1.180	0.988	1.032
50	1.013	1.046	1.068	1.015	1.062
100	1.129	1.058	1.069	1.042	1.127
150	1.248	1.113	1.196	1.068	1.069
200	1.321	1.195	1.155	1.111	1.019
250	0.946	1.165	1.211	1.129	1.136
300	1.329	1.205	1.277	1.114	1.138
400	1.449	1.280	1.140	1.189	1.188
500	1.529	1.295	1.239	1.184	1.128
600	1.266	1.451	1.263	1.191	1.125
700	1.177	1.229	1.234	1.237	1.169
800	1.341	1.305	1.484	1.292	1.157
900	2.126	1.429	1.331	1.301	1.134
950	1.666	1.361	1.294	1.231	1.122

TABLE 3.3 RELATIVE GAMMA MEASUREMENTS FOR ALL DOSIMETER TYPES AT ALL DISTANCES FOR EACH SHOT

Height ft	Boltzman	Wilson	Hood	Owens	Diablo
0	0.960	0.994	1.013	1.028	—
3	1.040	0.980	1.004	0.984	1.002
10	—	1.033	1.008	1.005	—
30	—	1.065	1.119	1.029	1.070
50	1.147	1.039	1.072	1.002	1.019
100	1.175	1.062	1.050	1.111	1.083
150	1.638	—	1.112	1.186	1.140
200	1.003	1.102	1.081	1.284	1.189
250	0.891	1.187	1.117	1.237	1.277
300	0.778	—	1.160	1.337	1.169
400	—	1.172	1.125	1.463	1.258
500	—	1.187	1.124	1.426	1.032
600	—	1.302	1.171	1.446	—
700	—	1.189	1.134	1.335	—
800	—	1.245	1.274	1.562	—
900	—	—	1.186	1.670	—
950	—	—	1.180	1.419	—

TABLE 3.4 RELATIVE GAMMA MEASUREMENTS FOR EACH DOSIMETER TYPE, FOR ALL RANGES

Height ft	NBS Film Badge	LSD Film Badge	Unshielded Film Packets	DT-60	Glass Needles	Quartz Fiber	AFSAM Chemical Dosimeters
0	—	1.029	0.995	1.038	0.990	0.981	0.886
3	0.984	1.042	1.007	1.009	1.023	0.981	0.886
10	1.119	0.955	1.169	1.012	0.985	1.021	1.226
30	1.744	1.063	1.243	1.153	0.907	1.119	0.949
50	1.100	1.067	1.060	1.064	1.048	0.985	0.937
100	1.109	1.111	1.191	1.023	0.876	1.044	0.926
150	1.122	1.173	1.328	1.114	0.914	1.184	1.169
200	1.103	1.073	1.279	1.115	0.932	1.175	—
250	1.064	1.142	1.203	1.126	1.109	1.234	1.214
300	1.065	1.073	1.291	1.125	0.914	1.208	—
400	1.194	1.121	1.433	1.186	0.911	1.158	—
500	1.135	1.079	1.600	1.265	0.943	1.075	1.014
600	—	1.157	1.450	1.151	0.923	1.195	1.083
700	—	1.182	1.496	1.077	0.796	1.183	1.071
800	—	1.071	1.635	1.281	0.916	1.319	1.060
900	—	1.274	1.626	1.391	0.976	1.014	—
950	1.205	1.150	1.501	1.252	1.102	1.181	—

TABLE 3.5A NEUTRON FLUX MEASURED WITH SULFUR

Height	Reading $\times 10^{10} n/cm^2$	Corrected Reading $\times 10^{10} n/cm^2$	Ratio: Corrected Reading to Ground Reading	Reading $\times 10^{10} n/cm^2$	Corrected Reading $\times 10^{10} n/cm^2$	Ratio: Corrected Reading to Ground Reading	Reading $\times 10^{10} n/cm^2$	Corrected Reading $\times 10^{10} n/cm^2$	Ratio: Corrected Reading to Ground Reading
ft									
	Shot Wilson, Station 1,500 yards			Shot Hood, Station 2,000 yards			Shot Owens, Station 1,500 yards		
0	1.32	1.32	1.000	1.29	1.29	1.000	4.08	—	—
3	1.29	1.29	0.977	1.50	1.50	1.162	3.01	3.01	1.000
10	1.26	1.26	.953	1.29	1.27	0.984	2.98	2.97	0.987
30	1.31	1.29	.981	1.48	1.45	1.124	2.99	2.93	0.973
50	1.39	1.35	1.023	1.64	1.60	1.238	3.18	3.11	1.033
100	1.46	1.39	1.051	—	—	—	3.51	3.38	1.123
150	1.66	1.54	1.169	1.62	1.49	1.156	3.43	3.27	1.086
200	2.18	1.97	1.495	1.77	1.58	1.226	3.66	3.45	1.146
250	1.65	1.46	1.102	1.85	1.61	1.248	4.14	3.88	1.289
300	1.76	1.52	1.151	1.98	1.68	1.302	3.97	3.69	1.226
400	2.46	2.02	1.527	1.85	1.49	1.157	4.10	3.75	1.246
500	2.05	1.61	1.217	—	—	—	4.19	3.79	1.259
600	2.20	1.66	1.253	2.40	1.78	1.375	5.61	5.04	1.674
700	2.22	1.62	1.226	—	—	—	4.73	4.23	1.405
800	2.23	1.60	1.209	2.42	1.69	1.311	6.42	5.70	1.893
900	—	—	—	2.64	1.79	1.389	6.42	5.75	1.910
950	2.28	1.61	1.217	2.36	1.59	1.229	—	—	—

TABLE 3.5B NEUTRON FLUX MEASURED WITH SULFUR

Height	Reading $\times 10^{10} n/cm^2$	Ratio: Corrected Reading to Ground Reading	Reading $\times 10^{10} n/cm^2$	Ratio: Corrected Reading to Ground Reading
ft				
	Shot Owens, Station 1,000 yards		Shot Owens, Station 1,500 yards	
0	4.16	1.000	—	—
1	4.19	1.007	—	—
2	4.08	0.981	3.06	1.000
3	4.17	1.000	2.98	0.974
4	4.08	0.981	3.00	0.980
5	—	—	2.98	0.974
6	4.18	1.005	3.12	1.020
8	4.16	1.000	2.98	0.974
10	4.16	1.000	—	—
12	4.07	0.980	3.00	0.980
14	—	—	3.15	1.029
16	—	—	3.01	0.980
18	4.30	1.034	3.13	1.023
20	4.27	1.026	3.11	1.016
25	4.28	1.029	3.09	1.009
30	4.22	1.014	3.23	1.056
35	4.19	1.007	3.15	1.029
40	—	—	3.32	1.085
45	4.39	1.055	3.22	1.052
50	4.42	1.063	—	—

TABLE 3.6 NEUTRON FLUX MEASURED WITH NUCLEAR TRACK FILM

Height	Reading Tracks/cm^2	Corrected Reading Tracks/cm^2	Ratio: Corrected Reading to Ground Reading	Reading Tracks/cm^2	Corrected Reading Tracks/cm^2	Ratio: Corrected Reading to Ground Reading
ft						
	Shot Wilson, Station 3,040 yards			Shot Diablo, Shasta Tower Station		
0	1,540	1,580	1	1,090	1,065	1
3	1,620	1,580	1	1,040	1,065	1
10	1,670	1,662	1.052	1,020	1,017	0.955
30	1,785	1,766	1.117	—	—	—
50	1,670	1,644	1.040	1,360	1,321	1.240
100	1,320	1,287	0.815	1,240	1,187	1.114
150	1,650	1,587	1.004	1,350	1,274	1.196
200	1,400	1,330	0.842	—	—	—
250	—	—	—	1,140	1,051	0.987
300	1,280	1,175	0.744	—	—	—
400	1,270	1,167	0.739	1,310	1,175	1.103
500	1,500	1,275	0.807	1,310	1,164	1.093
600	1,830	1,512	0.957	1,200	1,051	0.986
700	2,120	1,741	1.101	—	—	—
800	1,910	1,559	0.987	—	—	—
900	2,490	2,039	1.291	—	—	—
950	2,380	1,961	1.241	—	—	—

TABLE 3.7 NEUTRON DOSE MEASURED WITH CHEMICAL DOSIMETERS

Height	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading
ft	r	r		r	r	
	Shot Wilson, Station 1,500 yards			Shot Hood, Station 2,000 yards		
0	220	220	1.000	260	260	1.000
3	235	235	1.068	230	230	0.885
10	235	235	1.068	230	230	0.885
30	235	236	1.069	260	255	0.981
50	235	236	1.069	260	254	0.977
100	235	233	1.059	260	246	0.947
150	280	276	1.255	260	239	0.919
200	235	231	1.059	260	232	0.893
250	280	276	1.255	260	227	0.873
300	280	276	1.255	260	221	0.850
400	280	275	1.245	—	—	—
500	280	277	1.259	—	—	—
600	280	278	1.263	260	192	0.738
700	280	279	1.268	—	—	—
800	280	268	1.218	260	182	0.699
900	280	262	1.190	260	177	0.681
950	280	260	1.181	260	175	0.673

TABLE 3.8 GOLD FOIL AND FISSION FOIL MEASUREMENTS

Height	Foil Type	Reading	Corrected Reading Ground Conditions	Ratio: Corrected Reading to Ground Reading
ft		n/cm^2	n/cm^2	
Shot Hood, Station 2,000 yards				
3	Au	3.85×10^{10}	3.85×10^{10}	1.000
950	Au	6.99	4.58	1.190
3	Pu	15.0	15.0	1.000
950	Pu	20.7	1.36	0.906
3	Np	—	—	—
950	Np	11.5	7.55	—
3	U^{238}	1.98	1.98	1.000
950	U^{238}	4.97	3.26	1.645
Shot Diablo, Station Whitney Tower				
3	Au	1.00×10^{8}	1.00×10^{8}	1.000
250	Au	1.78	1.65	1.65
500	Au	2.21	1.94	1.94

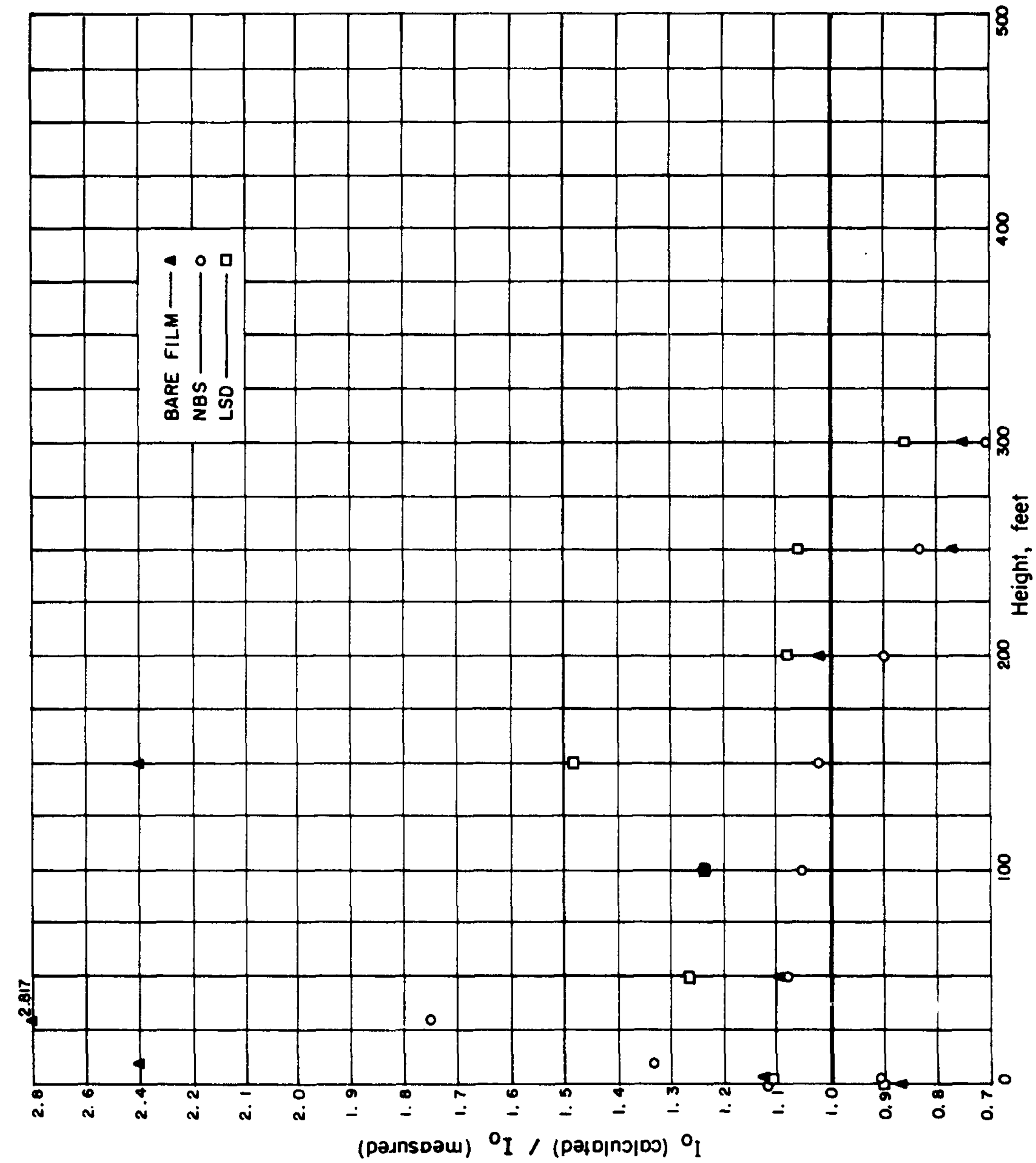

Figure 3.1 Relative total gamma dose as a function of height for Shot Boltzmann. All dosimeter types, Shot Franklin tower station (5,700 yd).

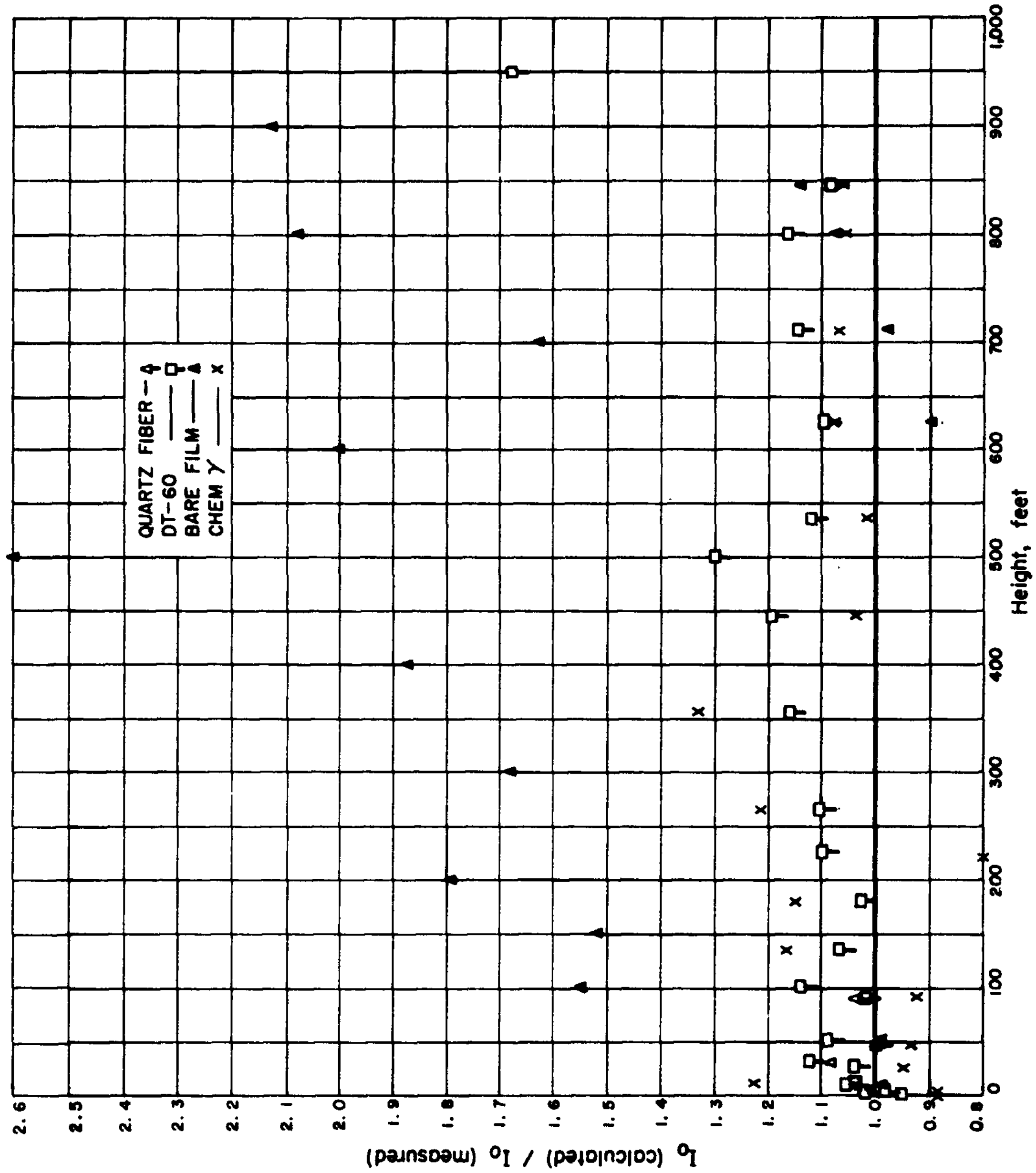

Figure 3.2 Relative total gamma dose as a function of height for all shots. All dosimeter types, station at 1,500 yards.

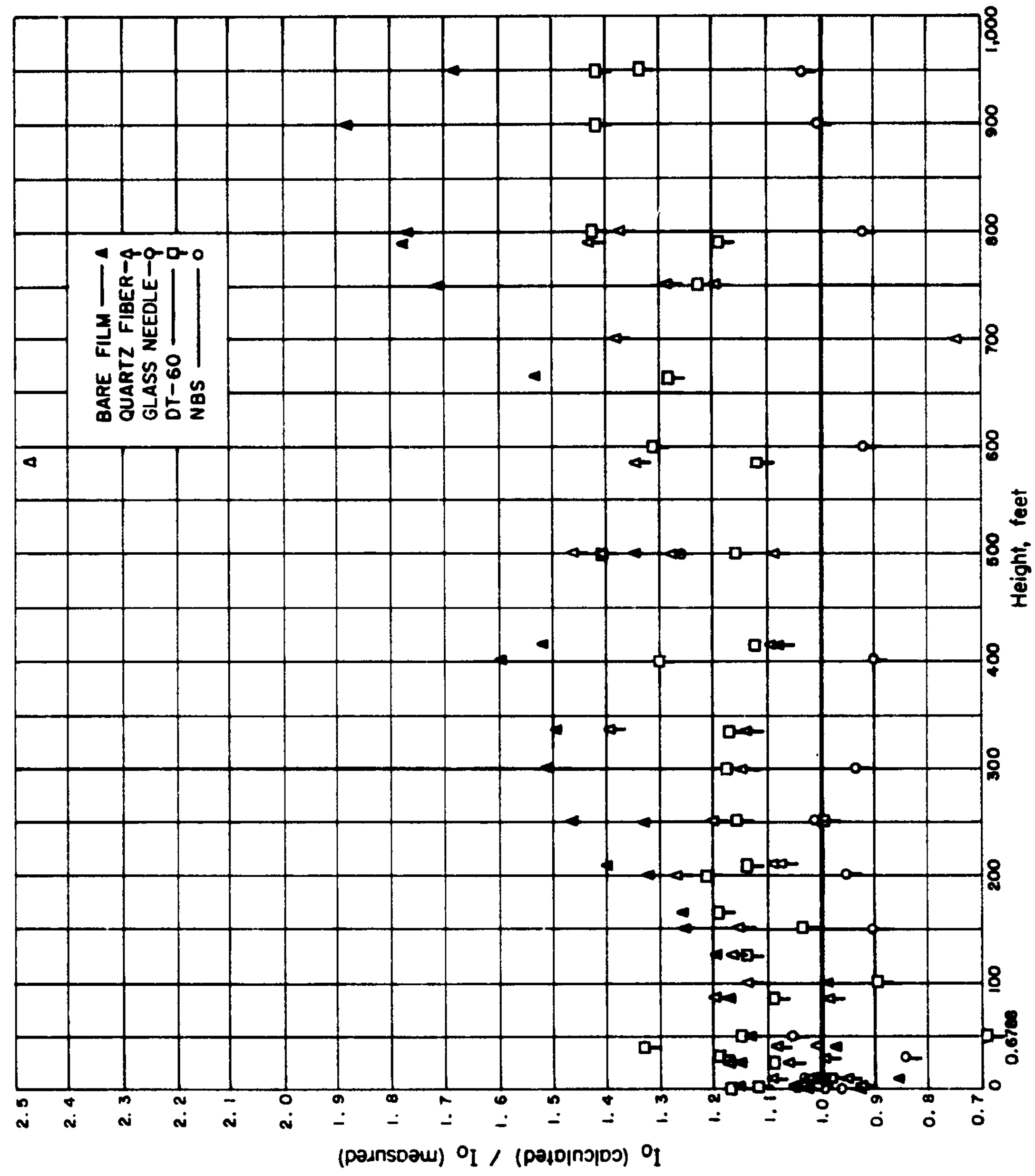

Figure 3.3 Relative total gamma dose as a function of height for all shots. All dosimeter types, station at 2,000 yards.

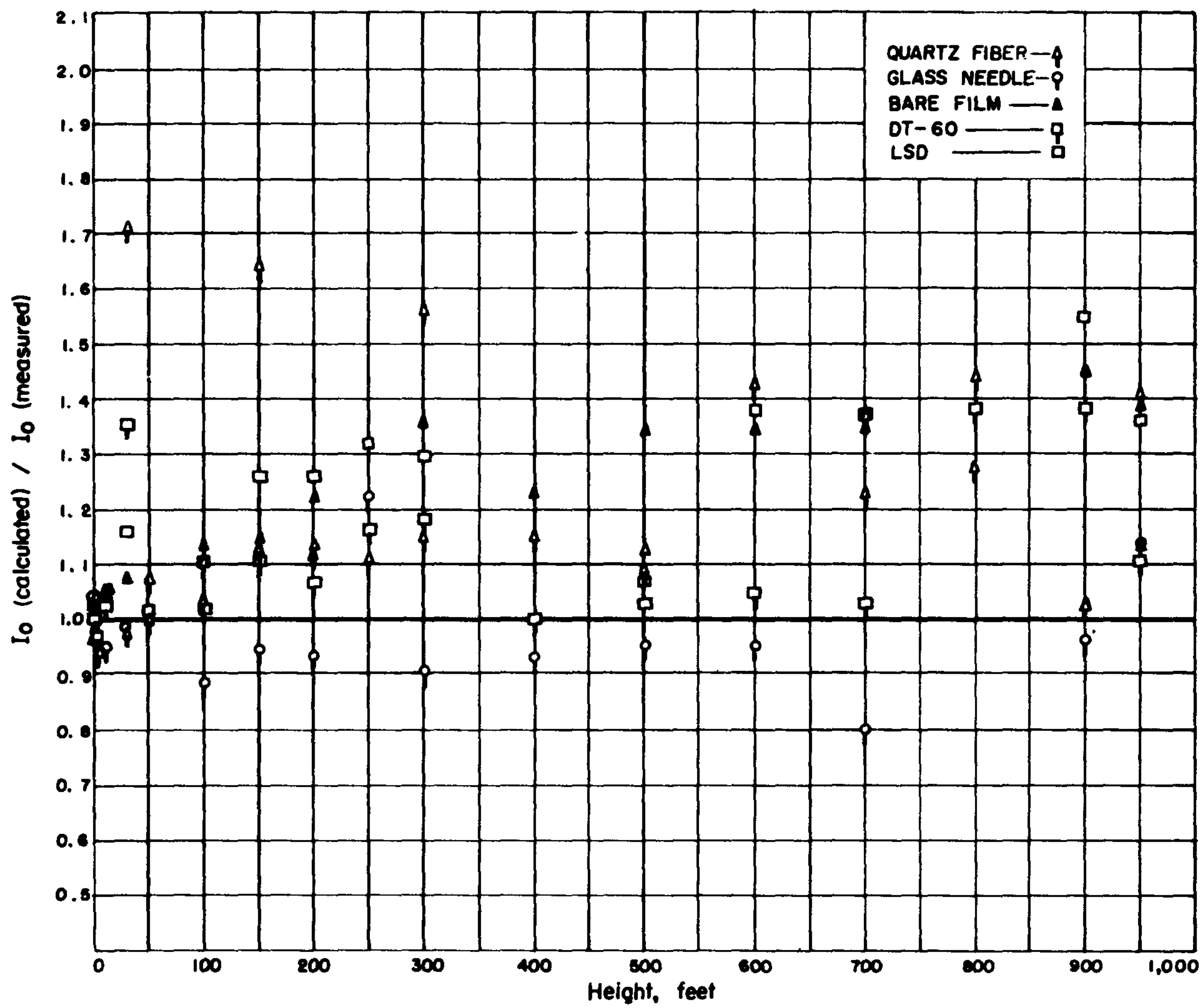

Figure 3.4 Relative total gamma dose as a function of height for all shots. All dosimeter types, station at 2,500 yards.

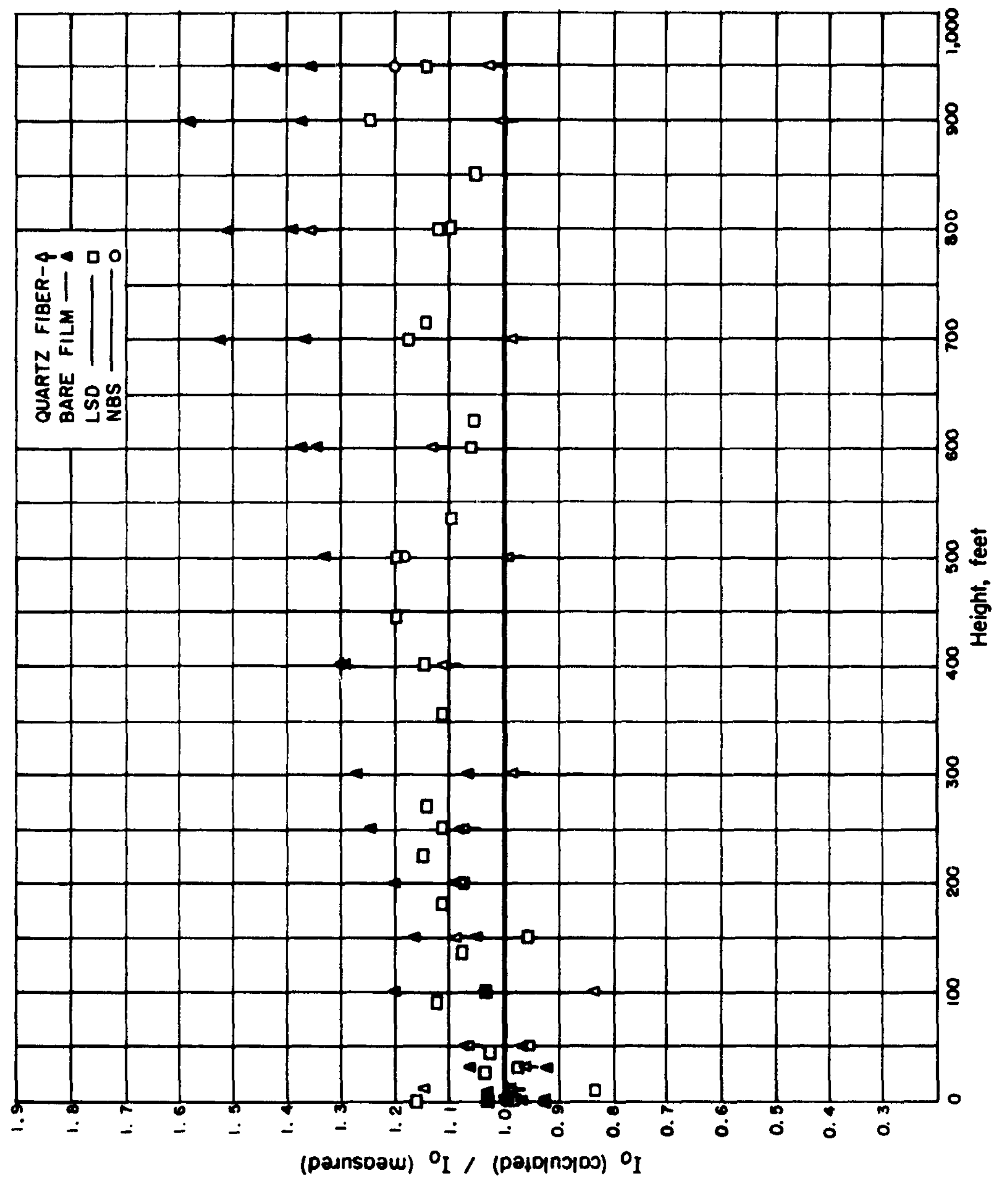

Figure 3.5 Relative total gamma dose as a function of height for all shots. All dosimeter types, station at 3,040 yards.

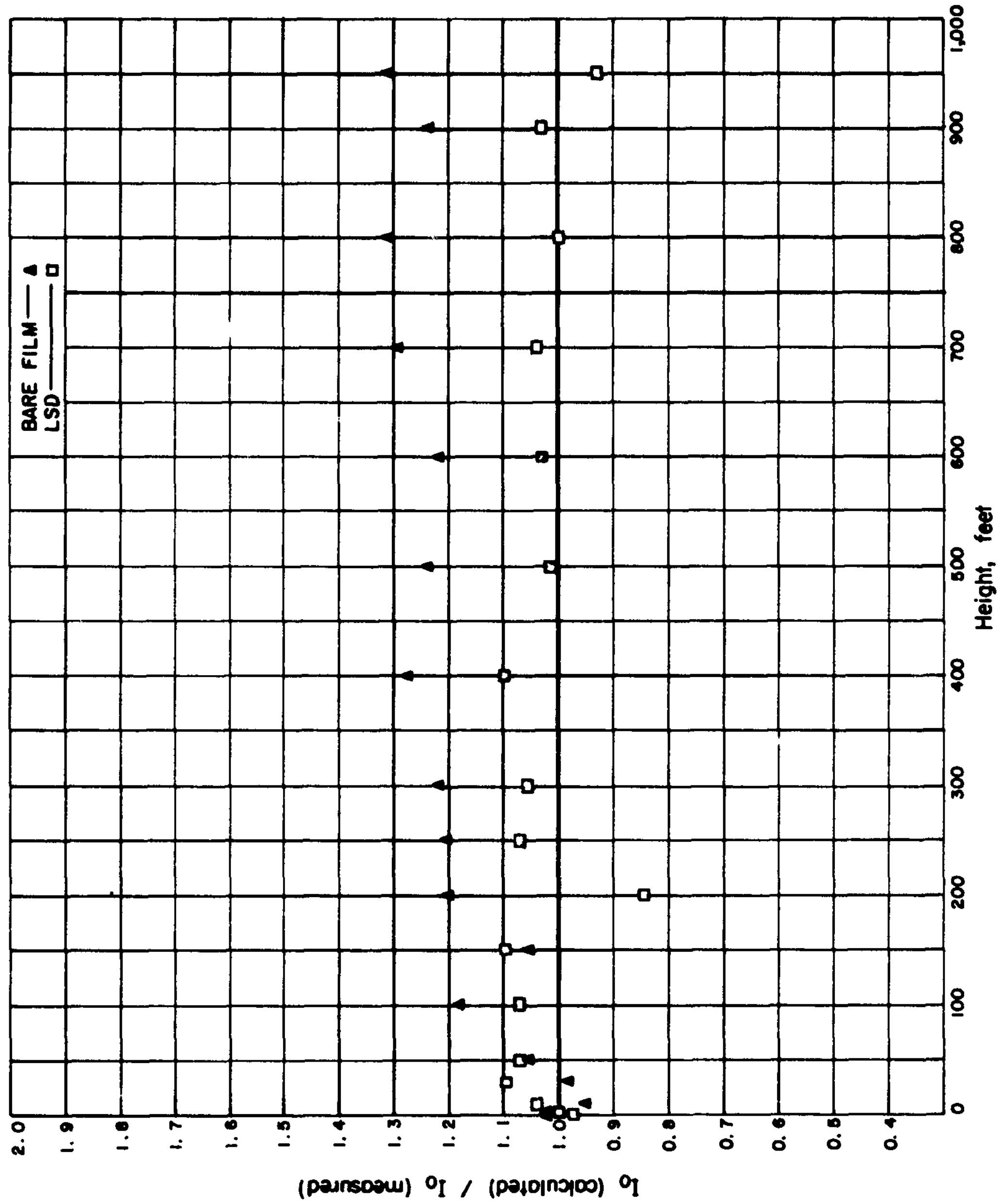

Figure 3.6 Relative total gamma dose as a function of height for all shots.
All dosimeter types, station 3,580 yards.

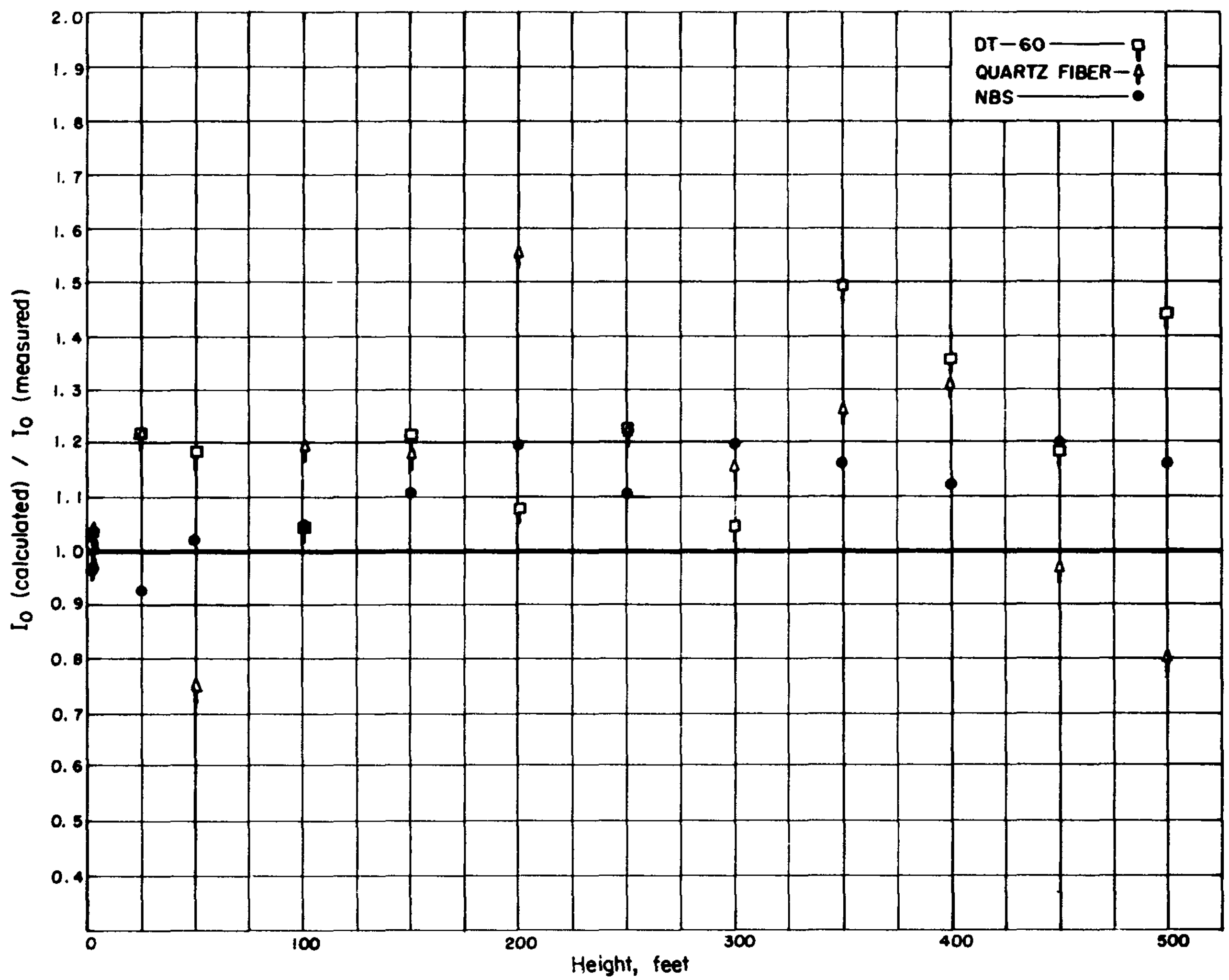

Figure 3.7 Relative total gamma dose as a function of height for Shot Diablo. All dosimeter types, Shot Whitney tower station (1,670 yd).

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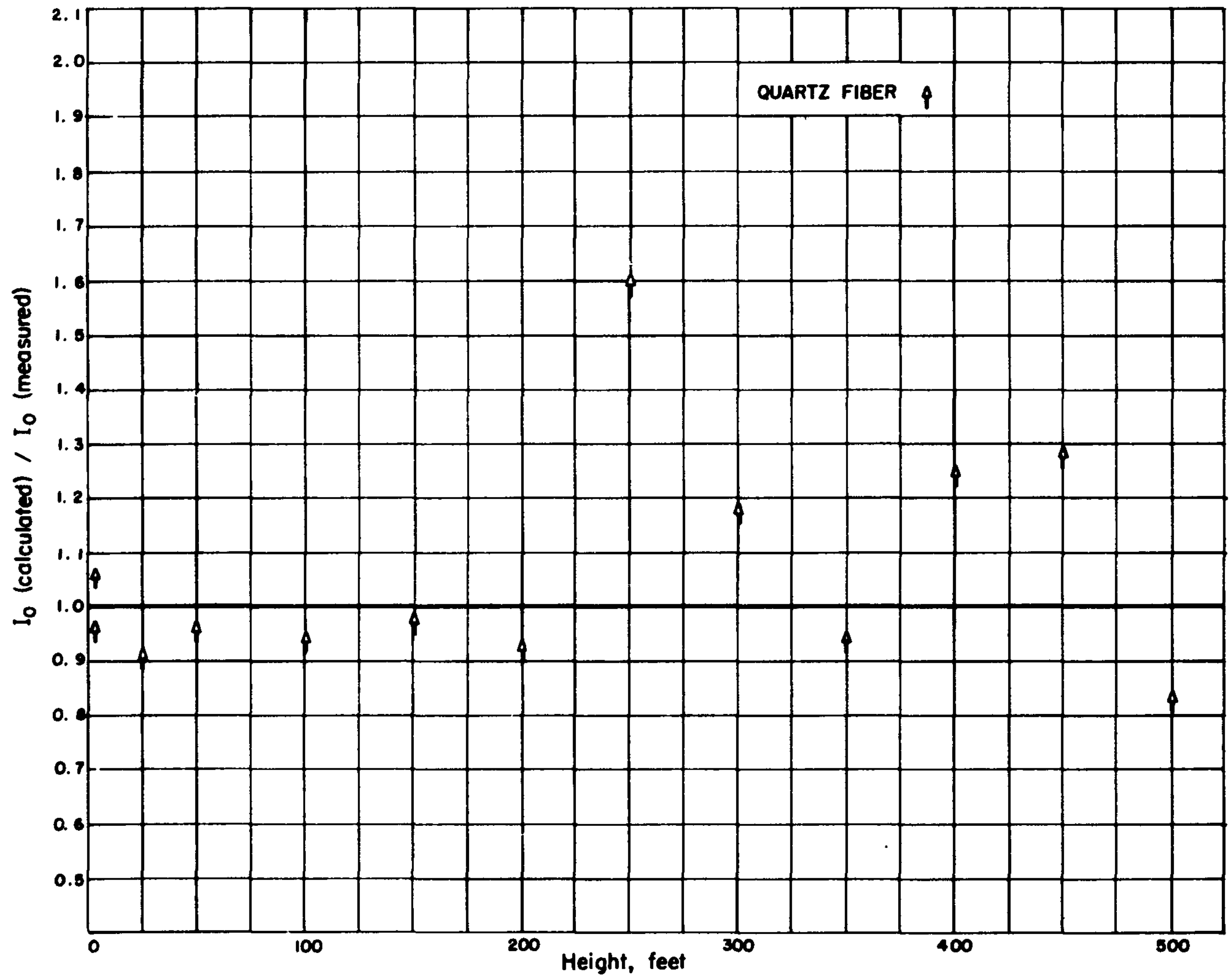

Figure 3.8 Relative total gamma dose as a function of height for Shot Diablo. All dosimeter types, Shot Shasta tower station (2,710 yd).

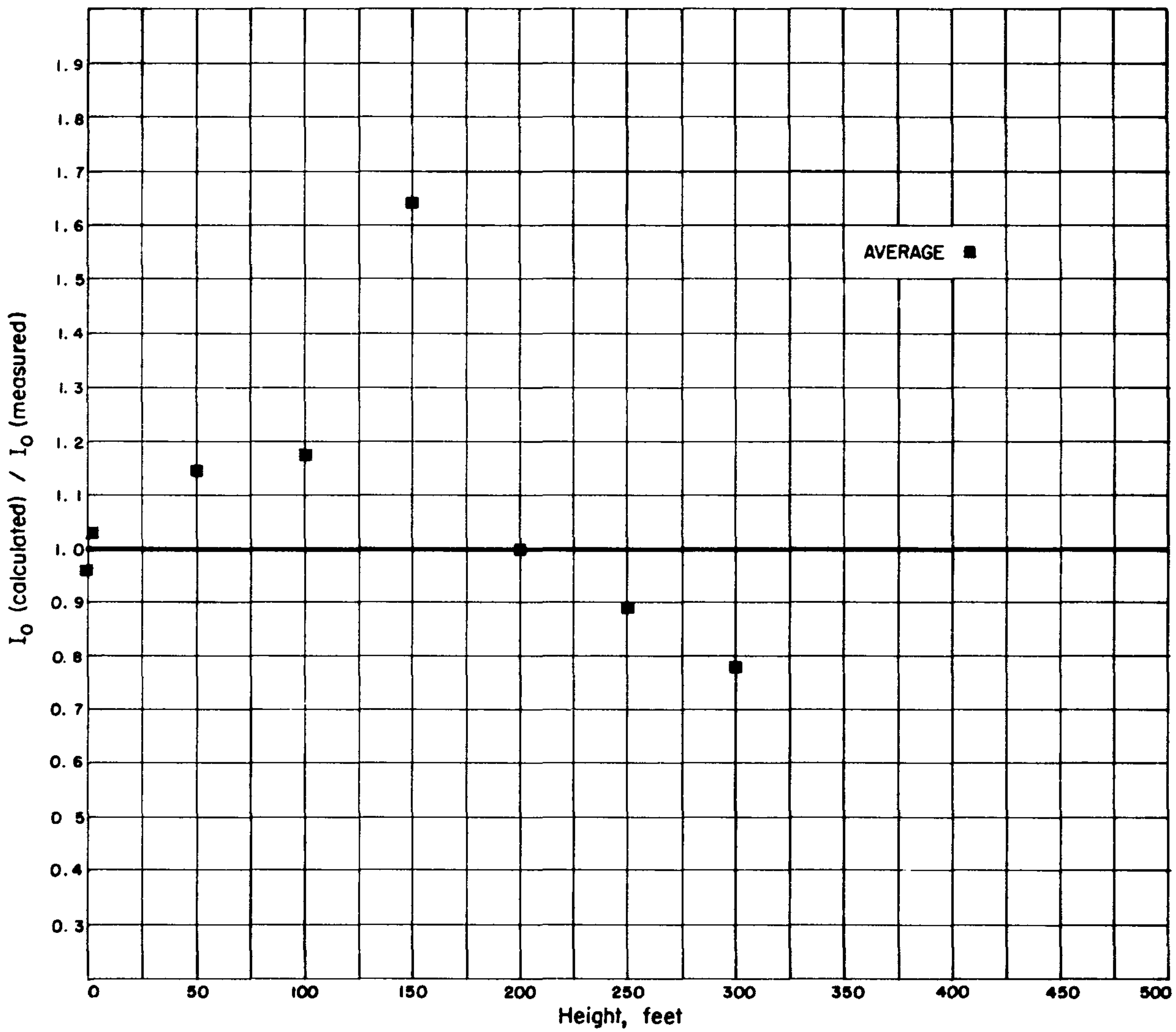

Figure 3.9 Relative total gamma dose as a function of height for Shot Boltzmann. All dosimeter types, all distances.

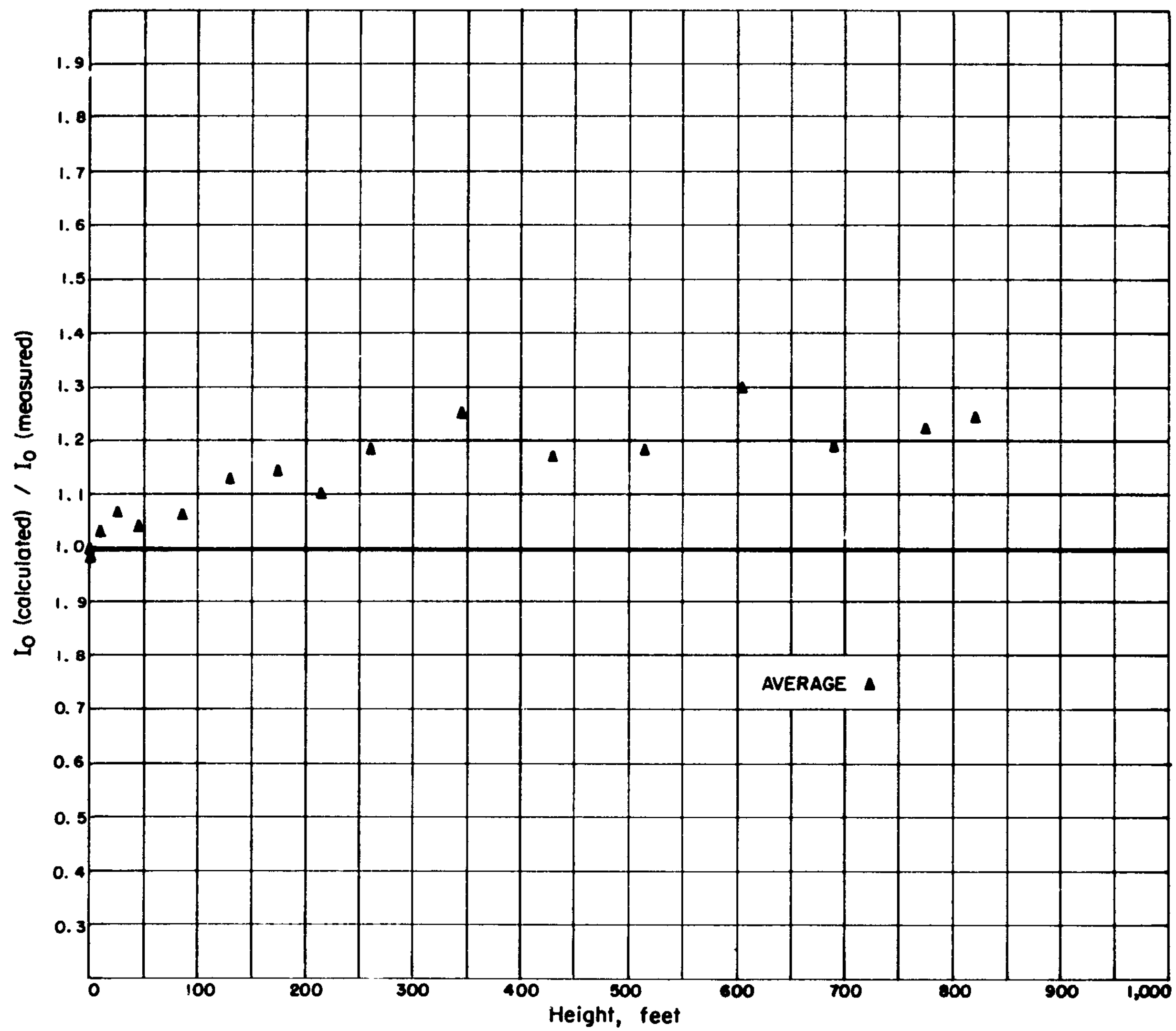

Figure 3.10 Relative total gamma dose as a function of height for Shot Wilson. All dosimeter types, all distances.

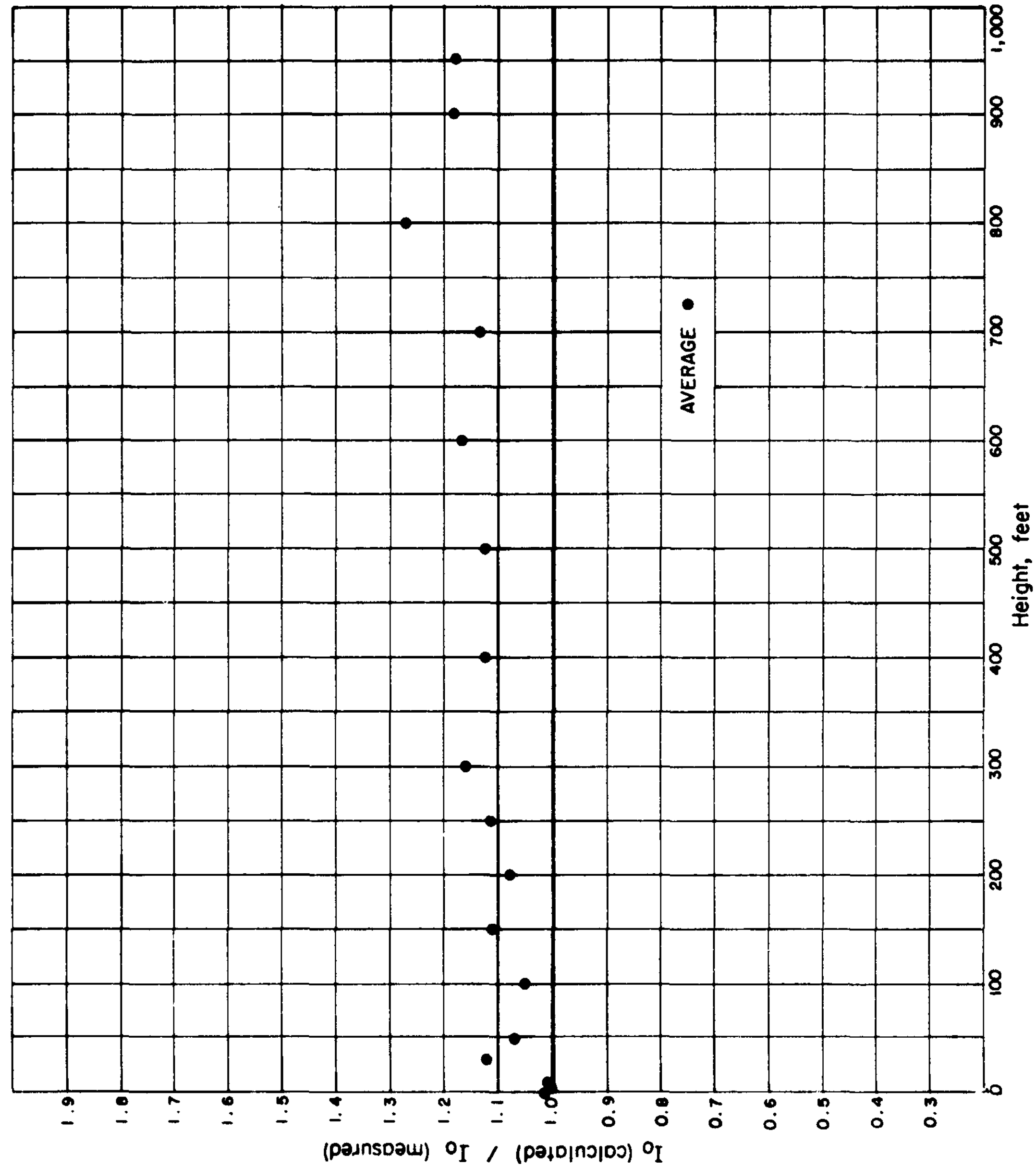

Figure 3.11 Relative total gamma dose as a function of height for Shot Hood. All dosimeter types, all distances.

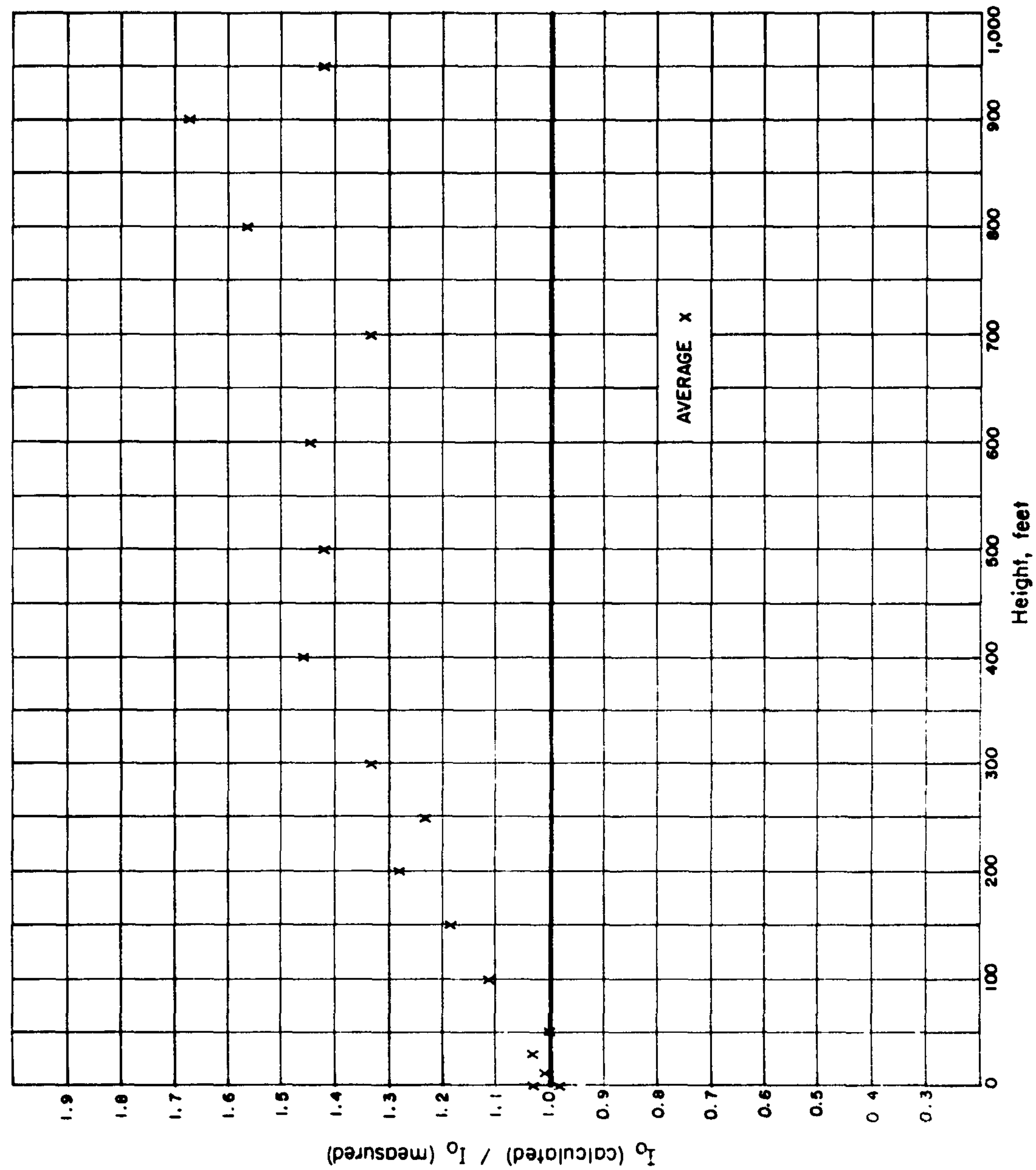

Figure 3.12 Relative total gamma dose as a function of height for Shot Owens. All dosimeter types, all distances.

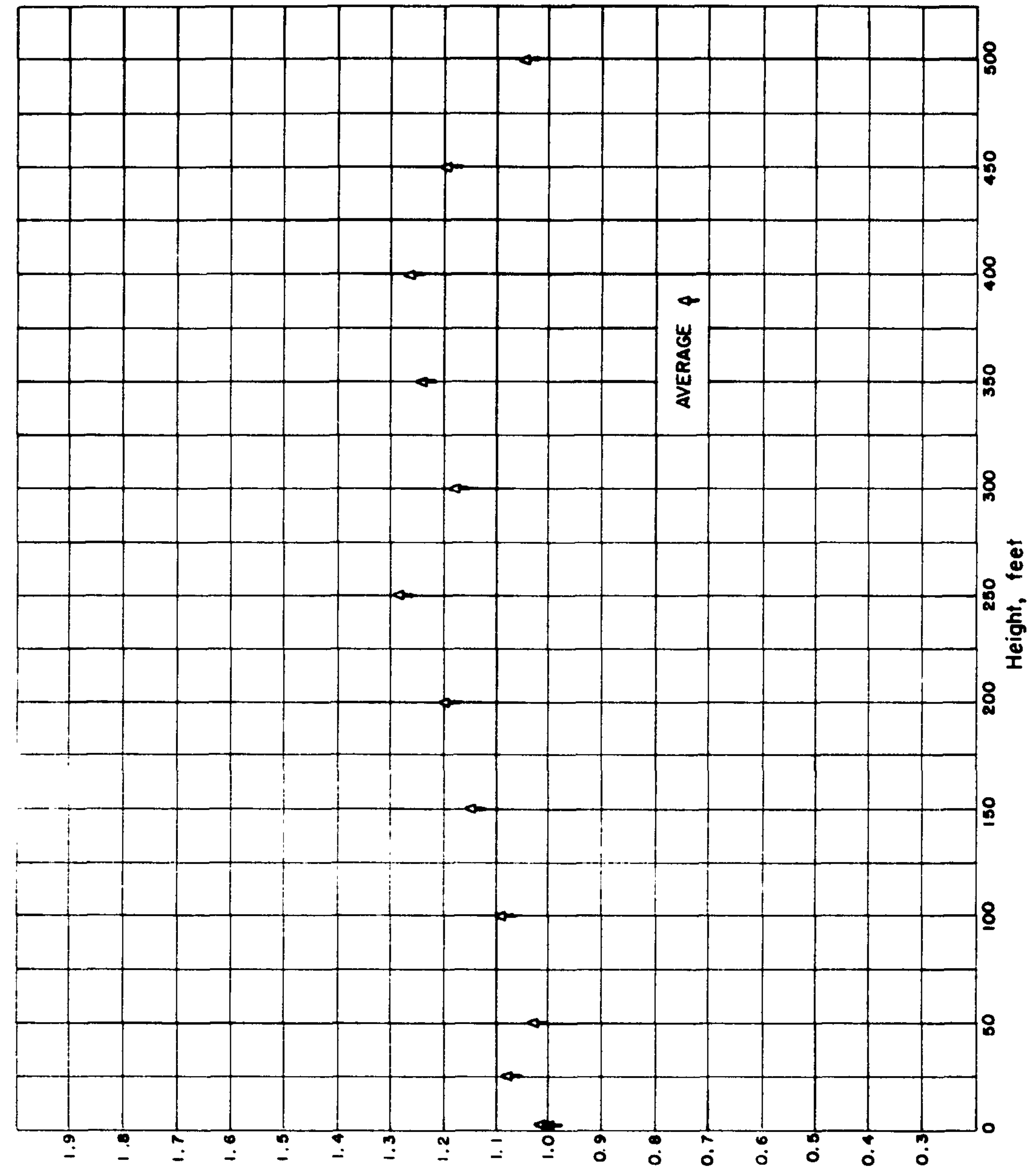

Figure 3.13 Relative total gamma dose as a function of height for Shot Diablo. All dosimeter types, all distances.

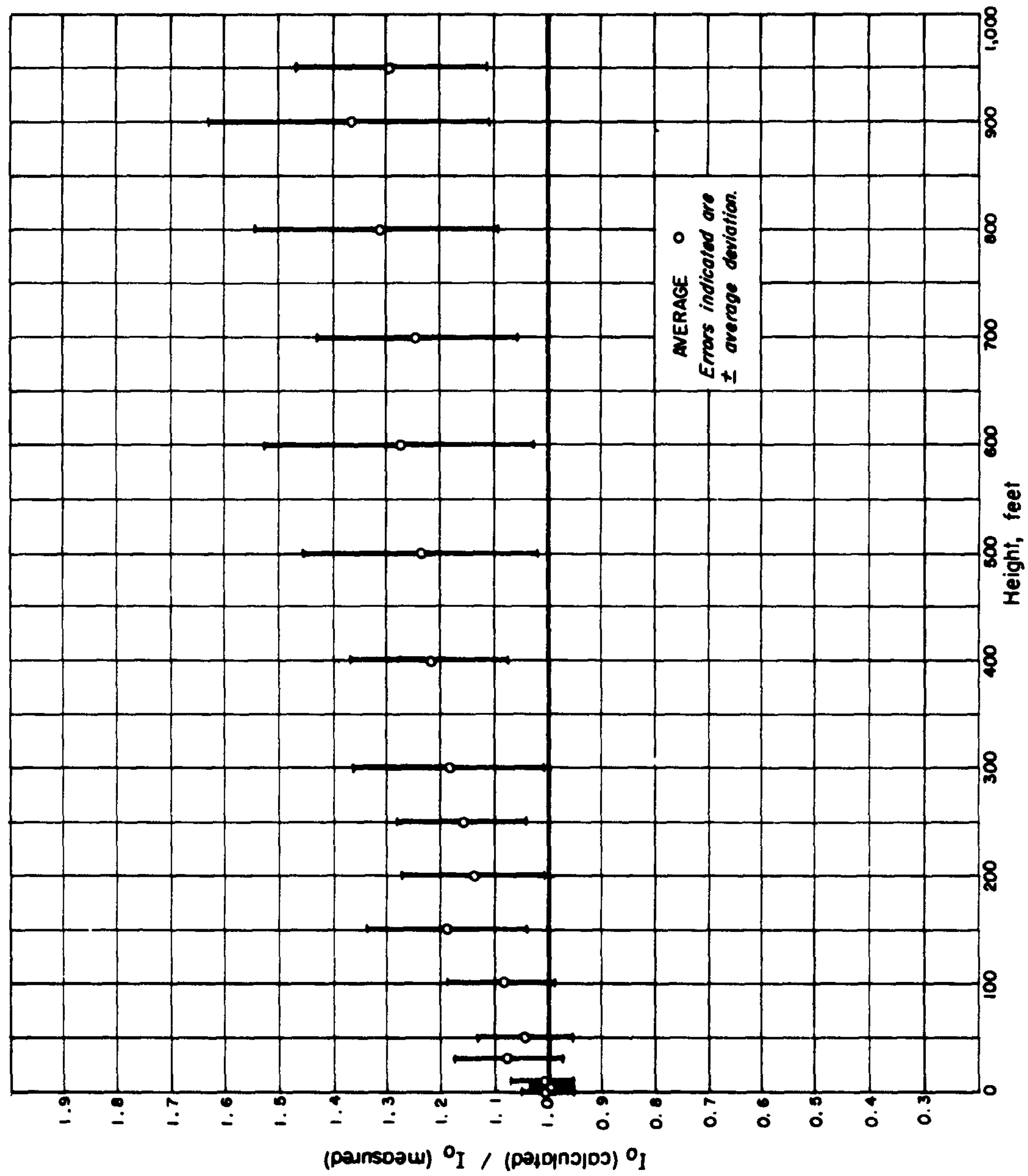

Figure 3.14 Relative total gamma dose as a function of height for all shots. All dosimeter types, all distances.

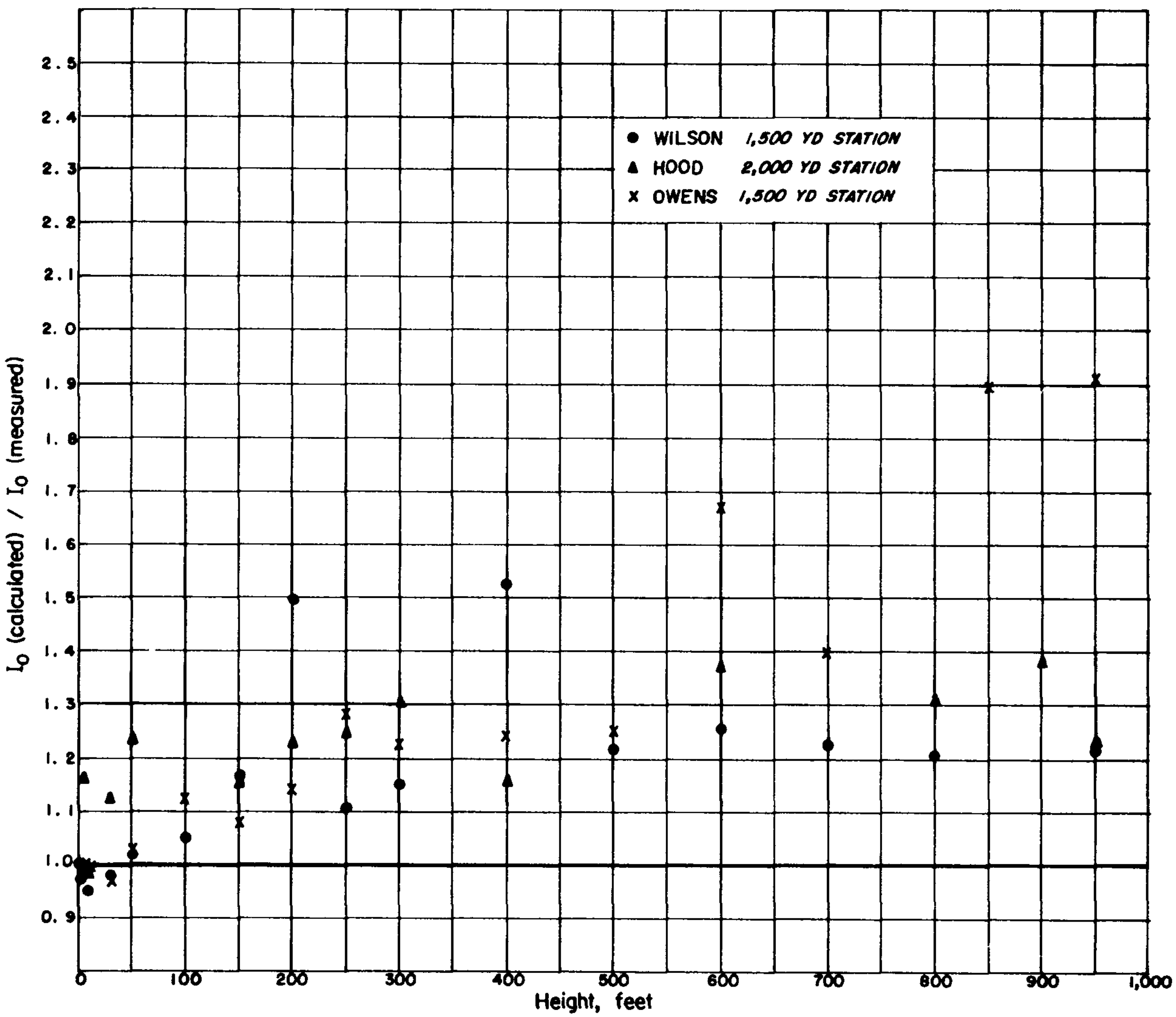

Figure 3.15 Relative neutron dose as a function of height for Shot Wilson, 1,500 yd station; Shot Hood, 2,000 yd station; Shot Owens, 1,500 yd station. All stations. Dosimeter type: sulfur.

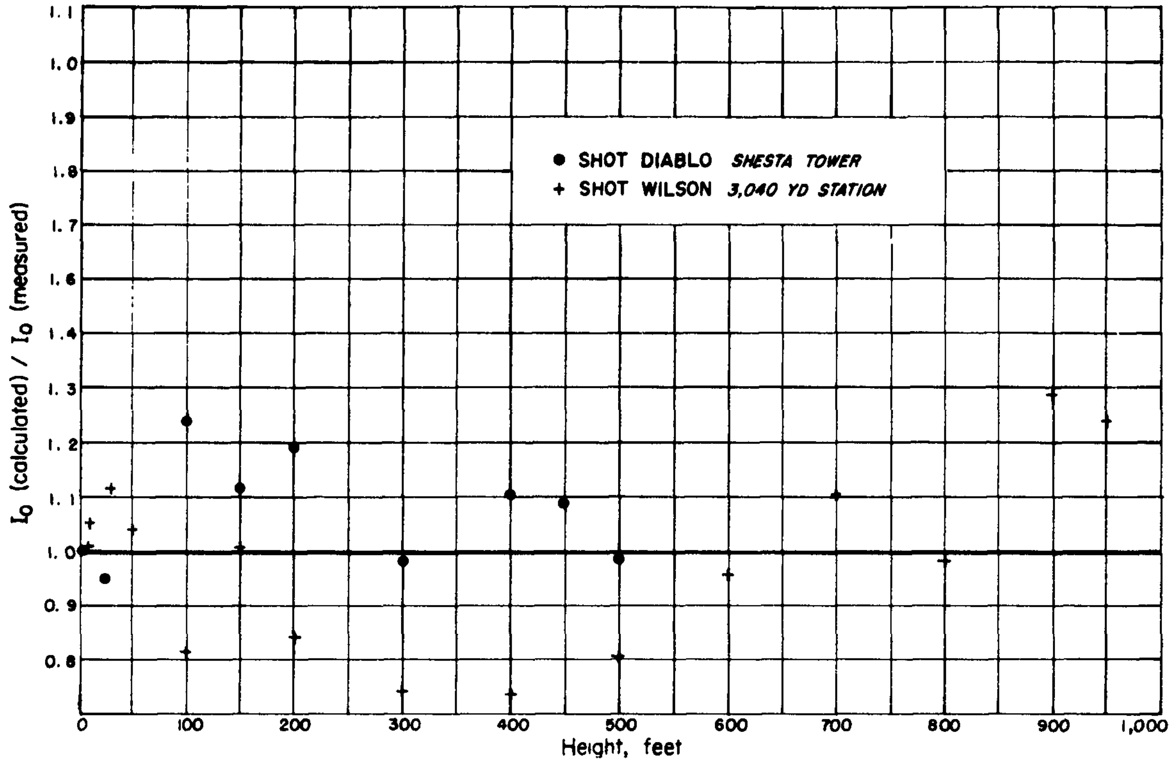

Figure 3.16 Relative neutron dose as a function of height for Shot Diablo, Shot Shasta Tower; Shot Wilson, 3,040 yd station. Dosimeter type: nuclear track film.

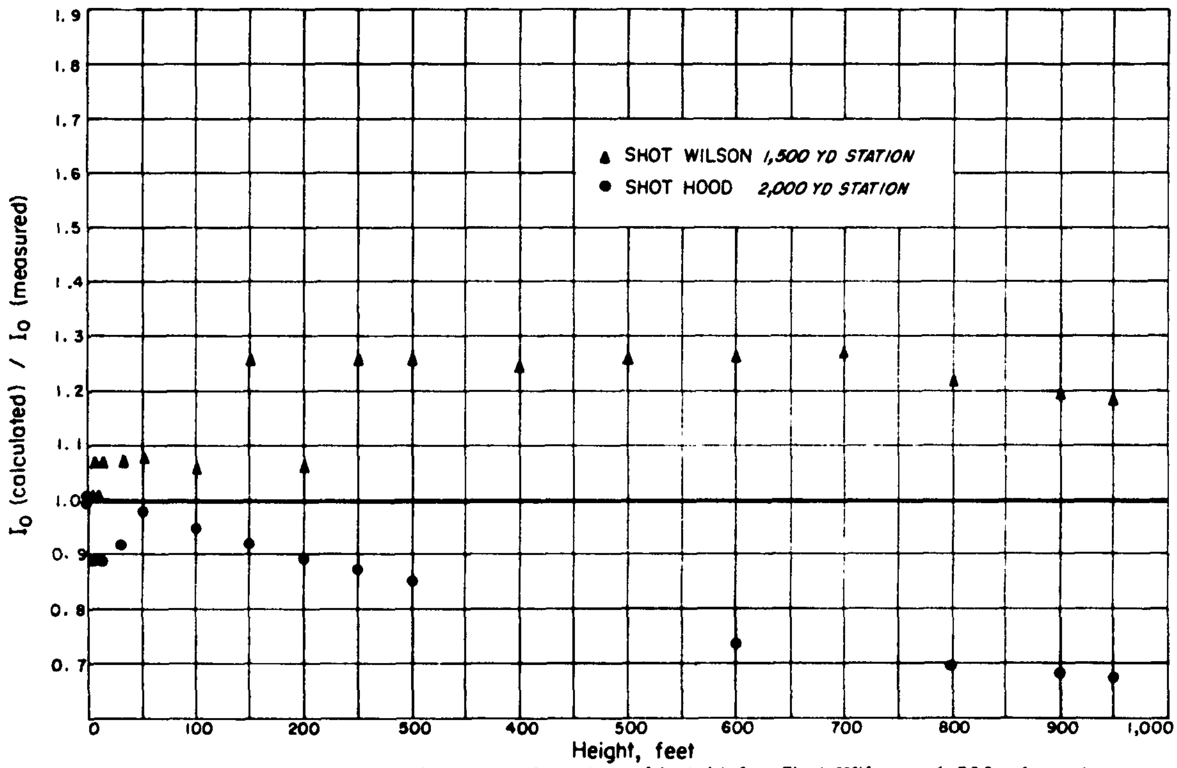

Figure 3.17 Relative neutron dose as a function of height for Shot Wilson, 1,500 yd station; Shot Hood, 2,000 yd station. Dosimeter type: chemical.

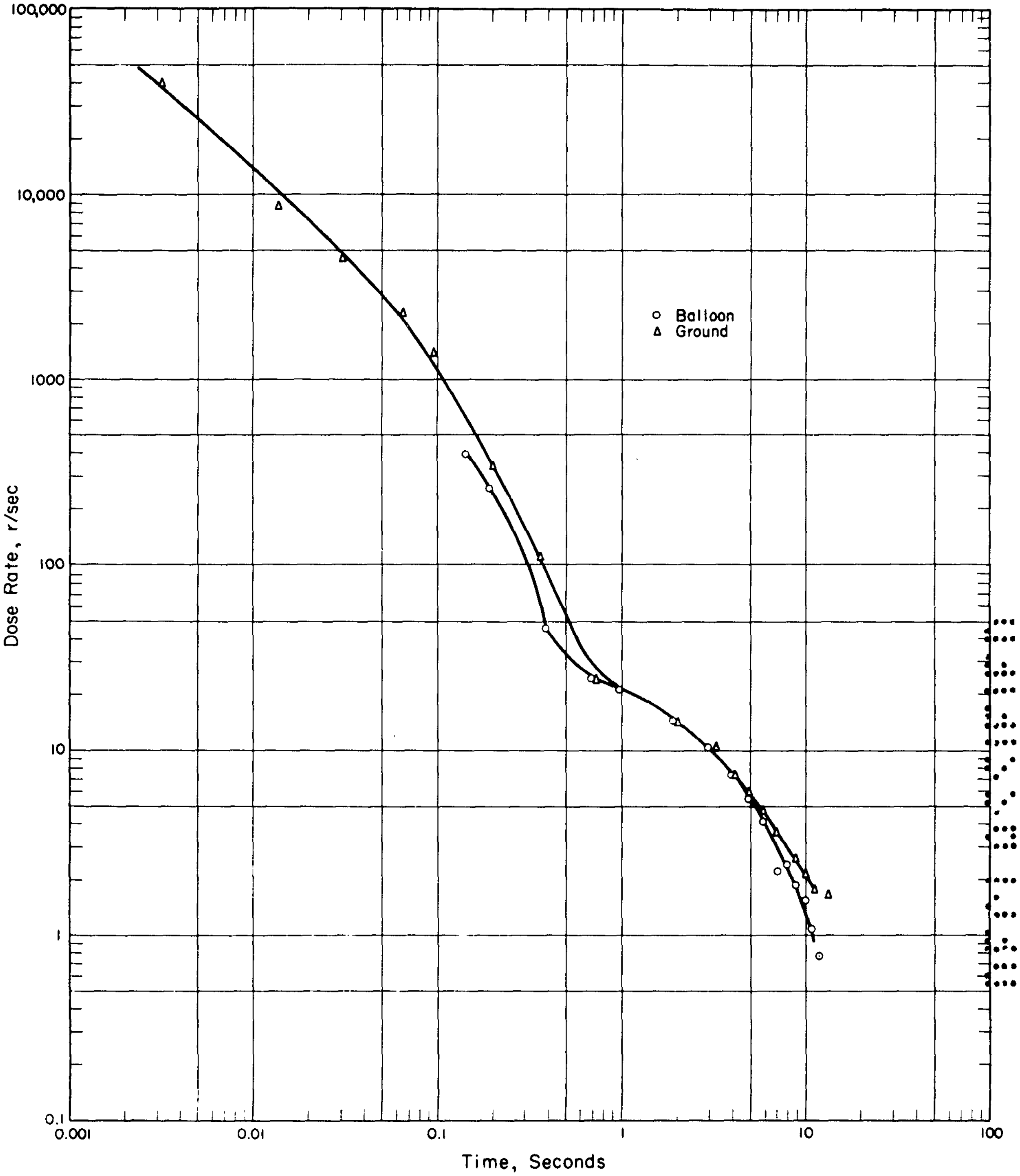

Figure 3.18 Gamma dose rate measurements for Shot Hood. Balloon station at 2,000 yds.

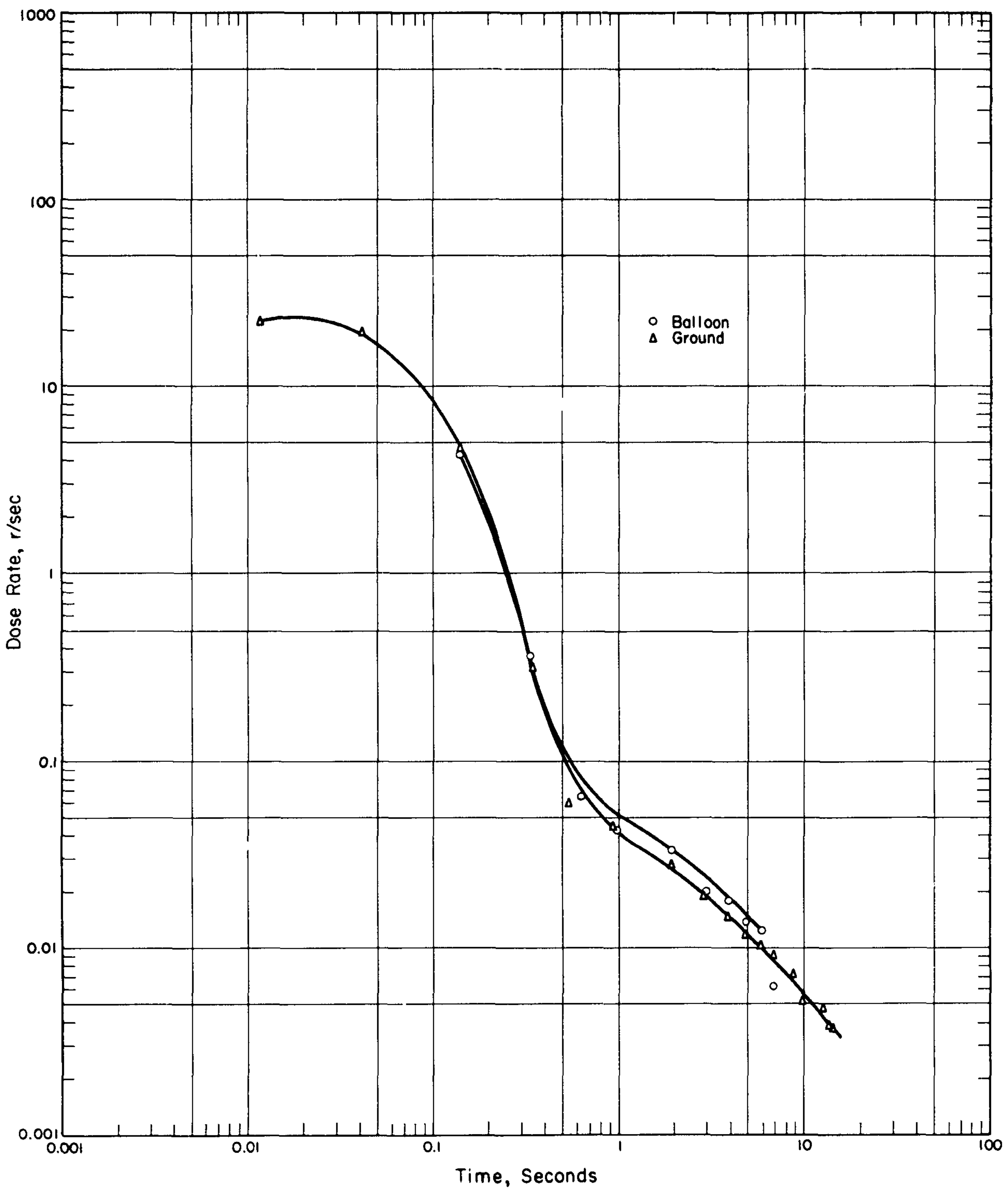

Figure 3.19 Gamma dose rate measurements for Shot Hood. Balloon station at 2,500 yards.

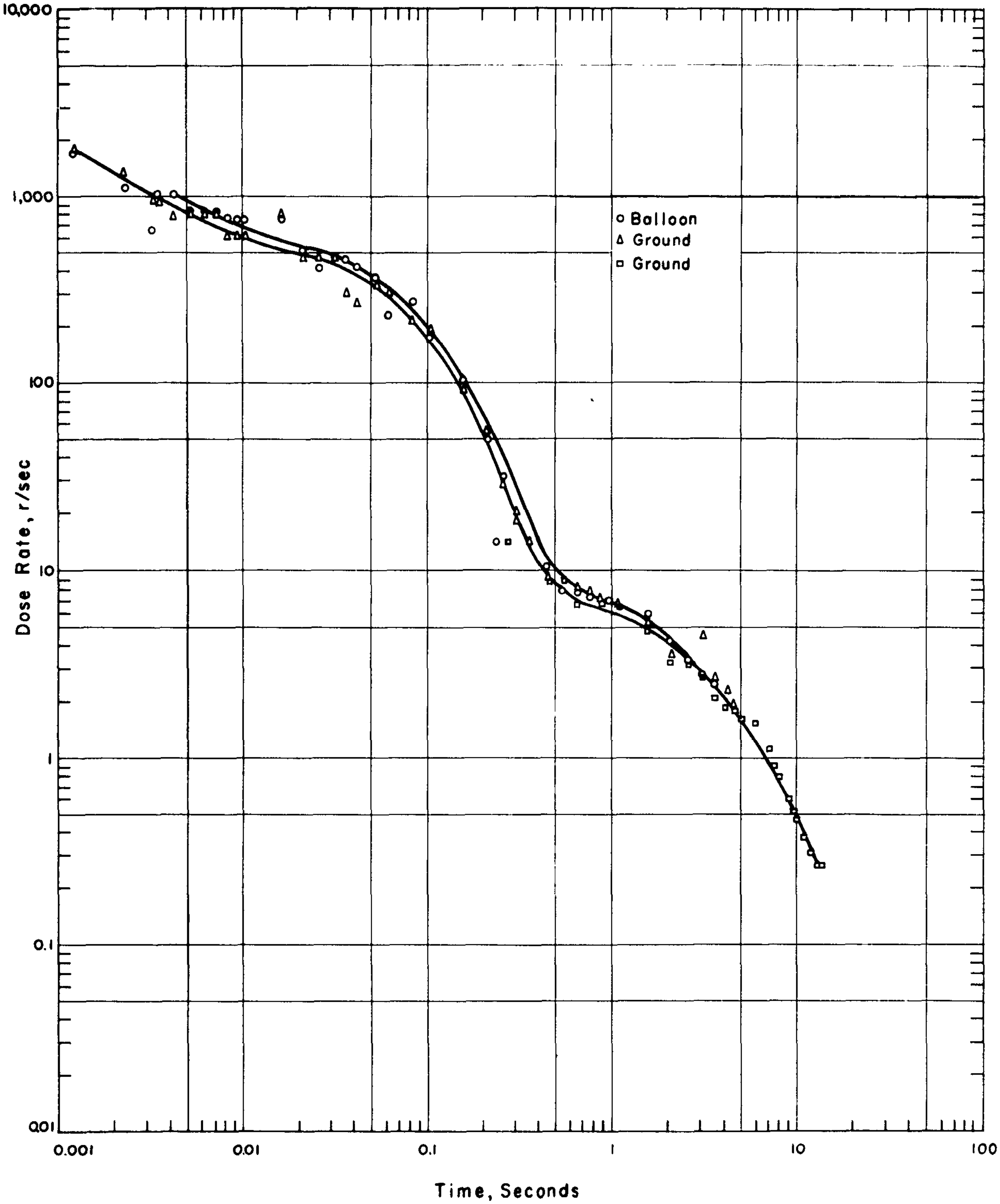

Figure 3.20 Gamma dose rate measurements for Shot Hood. Balloon station at 3,040 yards.

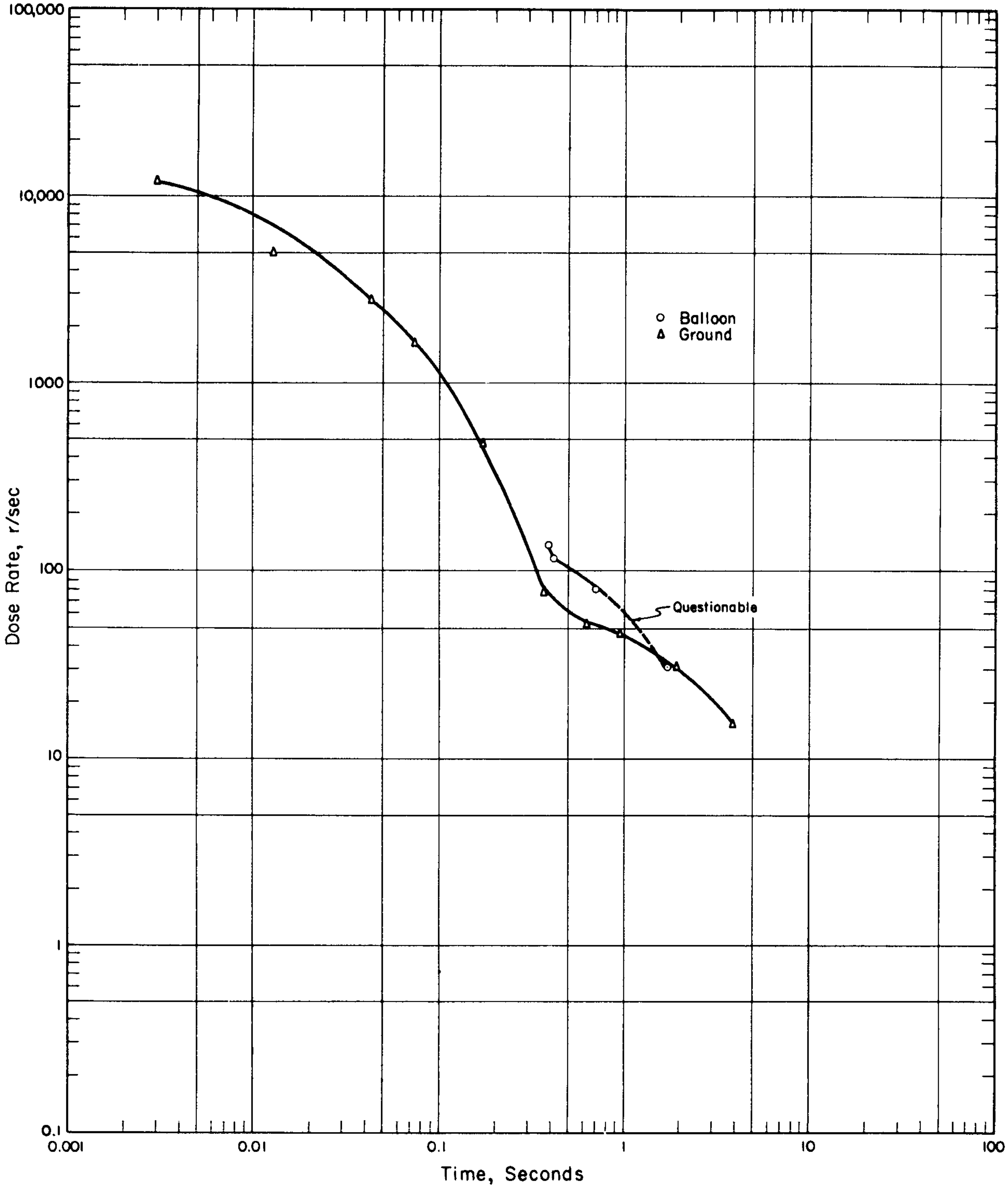

Figure 3.21 Gamma dose rate measurements for Shot Owens. Balloon station at 1,500 yards.

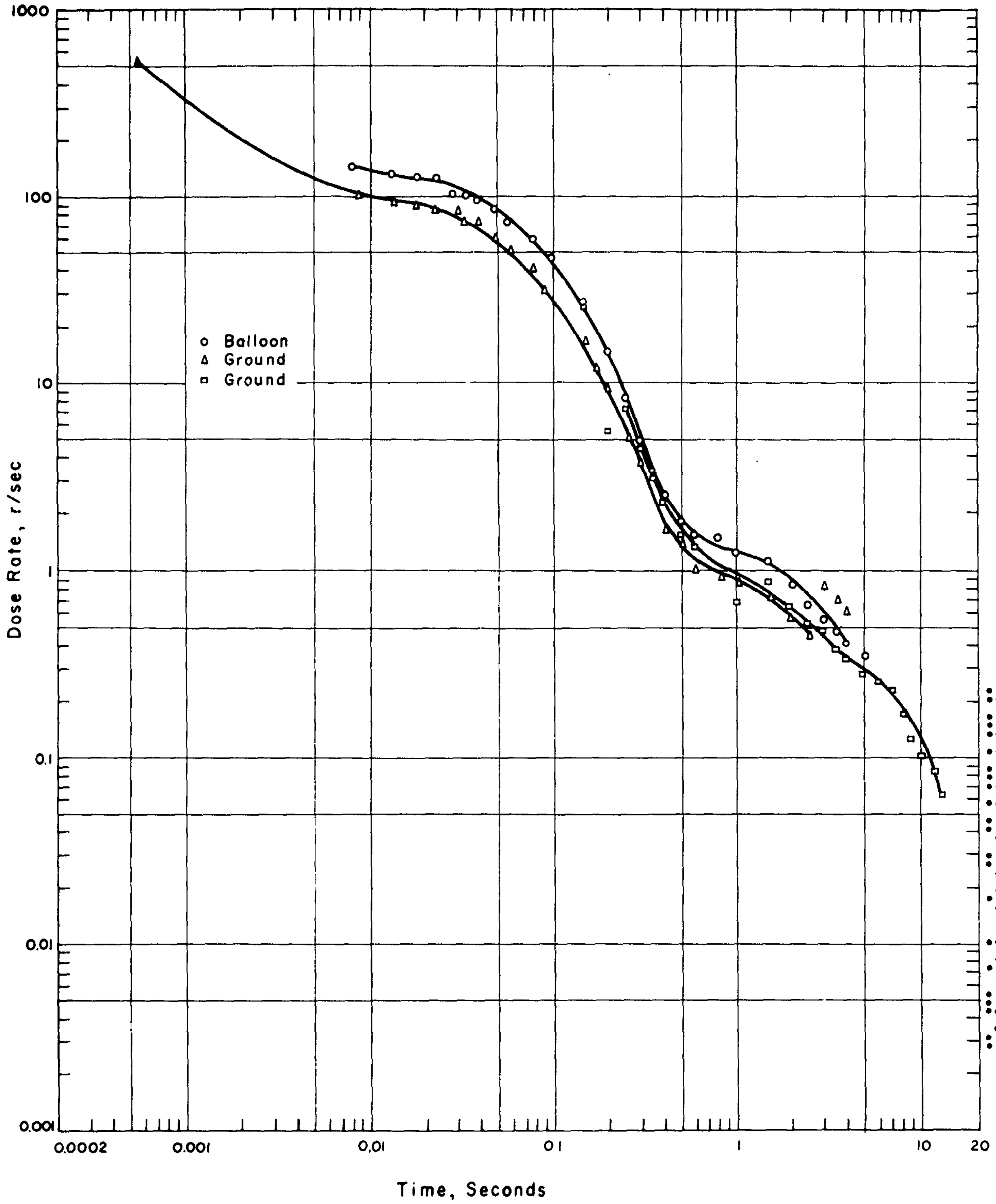

Figure 3.22 Gamma dose rate measurements for Shot Owens. Balloon station at 3,040 yards.

borne stations have been corrected for inverse-square dependence and for air density to give the dose rates equivalent to conditions at the ground stations. The dose rates from the ground stations have been corrected for the shielding introduced by the steel blast shields. The balloon-borne stations were encased in $\frac{1}{32}$-inch steel, which provided negligible shielding for the gamma radiation.

The small amount of useful dose-rate information from the balloon stations was not entirely unexpected, since in pretest planning it was felt that the probability of the instruments and coaxial cable surviving the electromagnetic pulse and the thermal pulse undamaged was low. Originally it was planned to use the gamma-rate instruments only at the two farthest balloons for each event. The total dosimeters were selected partly on the basis of keeping the total weight carried by each balloon approximately the same. On the balloons carrying the rate instruments, the weight of the total dosimeters was kept to a minimum. It was only after the performance of the balloons was found to be considerably better than expected that it was decided to put gamma-rate instruments on all four balloons.

Chapter 4
DISCUSSION

4.1 METHOD OF DATA CORRECTION

In order to compare measurements taken above the surface with measurements at the surface, it was necessary to apply corrections to the raw data. Differences in slant ranges and differences in air density between the ground stations and the air stations could cause relatively large changes in the measured dose. This might obscure any differences caused by the effect of the air-ground interface unless appropriate corrections were made. The following equation was assumed to describe the behavior of the initial nuclear radiation as a function of distance and air density.

$$D = \frac{D_0 W A}{x^2} \exp\left(-x\bar{\rho}/\lambda\right) \tag{4.1}$$

Where: D = radiation dose (roentgens or rep)

D_0 = a constant, usually called the intercept (roentgens × yd^2/kt)

W = yield (kilotons)

A = a correction factor to account for the air-ground interface effect

x = slant range from source to receiver (yards)

ρ = average air density from source to receiver relative to standard air density

λ = mean free path at standard air density (yards)

The relative dose at two different receivers is given by:

$$\frac{D_2}{D_1} = \frac{\dfrac{D_0 W A_2}{x_2^2} \exp\left(-x_2\bar{\rho}_2/\lambda\right)}{\dfrac{D_0 W A_1}{x_1^2} \exp\left(-x_1\bar{\rho}_1/\lambda\right)}$$

$$= \frac{A_2 x_1^2}{A_1 x_2^2} \exp\left[\frac{-(x_2\bar{\rho}_2 - x_1\bar{\rho}_1)}{\lambda}\right] \tag{4.2}$$

where subscript 1 refers to receiver 1 and subscript 2 to receiver 2.
The relative interface correction factor for the two receivers is given by:

$$\frac{A_2}{A_1} = \frac{D_2 x_2^2}{D_1 x_1^2} \exp\left[\frac{-(x_1\bar{\rho}_1 - x_2\bar{\rho}_2)}{\lambda}\right] \tag{4.3}$$

By selecting D_1 at the surface so A_1 is one, the value of A_2 can be determined. Actually D_1 was taken as the average of measurements at 0, 3, and 10 feet above the surface. There was no statistically significant difference in the dose at these three heights (Table 3.1) and using an

average reduced the data scatter. The air measurement D_2 was then corrected for inverse square dependence x_2^2/x_1^2 and for relative air density $\exp[-(x_1\bar{\rho}_1 - x_2\bar{\rho}_2)/\lambda]$. This gave the value of the air measurement corrected to ground conditions. The value of A_2 was then given by dividing the air measurement corrected to ground measurement. It is this ratio or relative dose that is shown in Tables 3.1 through 3.4 and Figures 3.1 through 3.14.

Slant range from the burst point to each dosimeter package was calculated from the balloon position at shot time. Balloon positions were obtained by triangulation from phototheodolite and GSAP cameras by Program 9. For Shot Wilson the farthest balloon was not visible on the photographs. The position of this balloon was calculated by assuming that its position relative to the ground anchor was the average of the relative positions of the other two balloons. On Shot Owens one of the camera plates was fogged so that only line of sight from one station was available. The surface winds at shot time were calm, so the balloons were assumed to be vertical. This is supported by the fact that after shot time the balloons descended within a few yards of the ground anchor. If the balloons had been displaced by wind, they would have descended some distance away from the ground anchors. On Shot Wilson there was some surface wind at shot time, and all the balloons descended at the horizontal distance limited by the mooring cable.

The slant ranges for the dosimeter packages along the balloon-mooring cable were calculated by assuming that the mooring cable was a straight line between the ground anchor and the balloon. Actually the mooring cable followed a catenary, but visual observation of the mooring cables during winds that displaced the balloons from over the ground anchor showed that the dip of the catenary was always slight. It was felt that any errors introduced by assuming a straight line could be neglected.

Air density as a function of altitude was determined from meteorological data taken from Yucca Flat during the morning of the shot. The relative air density from the burst point to each dosimeter package was obtained by taking the average of the air density at the burst point and at the height of the dosimeter package. In making data corrections, it was readily apparent that air density corrections were critical. A 1-percent change in air density was sufficient to cause a 15-percent change in the gamma-dose measurement. Fortunately, the usual meteorological information of temperature and pressure as a function of altitude permitted accurate calculation of the air density as a function of altitude. It is believed that the calculated air densities are accurate to one part in a thousand so that any errors due to incorrect air densities should be only 1 or 2 percent.

4.2 COMPARISON OF AIR GROUND DATA

4.2.1 Integrated Gamma Dose. It was planned to take sufficient measurements of total-gamma dose to determine the effect of the air-ground interface as a function of height and of horizontal distance. It was also planned to utilize as many dosimeter types as possible to insure that some unexpected response of a particular dosimeter would not obscure the results. Another reason for taking a large number of measurements was to obtain statistically valid results with dosimeters that were known to vary 15 to 20 percent when used under field conditions. One unknown factor that cast considerable doubt on the wisdom of using total dosimeters was the effect of the movement of the dosimeters after shot time when the balloons would be destroyed. It was largely for this reason that gamma-rate measurements were taken at the balloon positions. The movement of the balloon after shot time (and hence the rate instrument) could be determined by photography. From the known position as a function of time, it would be possible to make corrections for any changes in slant range and air density as the detectors fell.

From a GSAP camera record, from examinations of the balloons during recovery, and from the visual observations of three balloons, it appeared that the sequence of balloon destruction was softening and some melting of the polyethylene by the thermal pulse, rupture of balloon case, and expulsion of helium by the negative pressure wave. Then the balloon descended under gravity with the balloon material acting as a drag. Apparently no appreciable lateral movement occurred, and no falling began for at least 2 or 3 seconds. Thus, at least 80 percent of the total dose was received before any movement of the dosimeters took place. In three cases it is known

that the balloons were airborne for over 10 seconds, so that virtually all the gamma dose was received with the dosimeters (with the possible exception of those closest to the ground) under free-air conditions.

All the objectives of the integrated-gamma measurements were achieved. An examination of the data listed in Tables 3.1, 3.2, 3.3, 3.4 and in Figures 3.1 through 3.14 shows that the total gamma dose increased with height above the surface up to about 400 feet. From 400 to 950 feet there was little or no increase in total gamma dose. The magnitude of the increase was considerably less than expected, being only about 30 percent. The individual dosimeters varied considerably as expected. The average deviation of the individual measurements from the mean was about 25 percent. The results were statistically valid, however, since if the deviations were considered to be random, the root-mean-square standard deviation from the mean was only 4 percent.

There was no difference in the effect of the air-ground interface as a function of distance from burst point over the range of 1,500 to 3,580 yards. All the stations showed similar results, an increasing dose with height up to a 30-percent increase at 400 feet and no further increase up to 950 feet. It was expected that the interface effect would increase with increasing horizontal distance, but no evidence for an increase with distance was found.

The different dosimeter types showed a considerable variation in response. The unshielded film packets showed the biggest increase in response as a function of height. This was about 50 percent increase for stations above 400 feet. The glass needles and chemical dosimeters showed the least response, since they indicated no increase in dose with height.

The above findings were not consistent with the hypothesis that multiple scattering is important in determining the gamma radiation dosage from nuclear detonations. The expected air-ground interface effects were based on calculations in which multiple scattering was important. The calculated effect of the interface was to reduce the multiple scattered components of the gamma radiation. Since the interface effects were much less than expected, the multiple scattered radiation must not be as important as was thought in determining the gamma radiation dose.

Based on the evidence presented above, it is postulated that the gamma-radiation dosage from a nuclear detonation comes primarily from unscattered radiation. There is, of course, a small amount of scattered radiation, and the ground surface is expected to reduce this component. Since the difference between ground measurements and free-air measurements was only 30 percent, the total contribution to the dosage by scattered radiation must have been of this order rather than having been several times as great as the direct radiation. The scattered radiation must have been of low energy, since the greatest effect was observed on unshielded film packets, which are sensitive to low-energy gamma radiation.

If this postulate is correct, it is expected that the gamma radiation from nuclear detonation is nearly mono-directional, that the energy distribution does not change with distance, and that shadow shielding which might be imposed by structures such as aircraft engines for single-engine jet aircraft would be effective in reducing initial gamma-radiation dosage. It is hoped that the results of other projects at Operation Plumbbob, particularly the Civil Effects Test Group collimation studies and the aircraft participation will shed more information on whether these expectations are correct or not.

4.2.2 Neutron Measurements. The neutron flux and dose measurements were not completely successful. Only one fission-foil measurement under free-air conditions was obtained. On this one measurement, there was considerable difference between the flux measured by U^{238} and Pu in comparison with ground measurements, so the variation in dose with height based on this one measurement is questionable. The chemical dosimeters showed no increase of dose with height; in fact, the average value showed a slight decrease. Based on the limits of the dosimeter readings, the maximum uncertainty in the dose values was about 20 percent. Since no increase of dose with height was observed, if there were an increase, it must have been 20 percent or less. Any amount greater than this should have been observed.

The neutron-flux measurements with sulfur pellets were successful for one station during Shots Wilson, Hood, and 2 stations on Shot Owens. No evaluation was made of the effect of the air-ground interface on sulfur neutron flux as a function of horizontal distance, since only one station was within range to obtain useful measurements on any one shot. The ratio of the air measurements to ground measurements, shown in Table 3.5 and Figure 3.15, increased with height to a value of about 1.3 at 500 feet. There was no further increase with height up to 950 feet. This 30 percent increase of free-air flux over flux measured at the ground was comparable to the 30 percent increase observed for gamma dose measurements. Three of the sulfur pellets on Shot Owens and two on Shot Wilson had counting rates considerably higher than average. The reason for this is not known but is presumed to be due to contamination or to counting errors. These five measurements were not included in the average values.

Results were obtained with nuclear track emulsions during Shots Wilson and Diablo. Only the total number of proton recoils were counted. No attempt to determine the neutron dose or energy was made. Since the effective energy threshold for proton recoils with the system used is about 0.3 Mev, the results obtained will be a relative measure of the neutron flux above 0.3 Mev.

4.2.3 Gamma-Rate Measurements. Measurements of partial gamma dose rate were obtained from three stations during Shot Hood and two stations during Shot Owens. In each case, the balloon-borne instrument was 950 feet above the surface at shot time. The free-air dose rates are compared with the corresponding ground station dose rates in Figures 3.18 through 3.22. Since the records are all short (only a few seconds except for one station on Shot Owens), the balloon-borne instruments are not believed to have moved appreciably from their position at shot time. Also, because of changes in the source location, the fireball does not rise enough in 2 or 3 seconds to introduce changes in slant range and air density. For longer times, of course, corrections must be made for rise of the fireball.

The balloon-borne instruments were corrected for slant range and air density at shot time. The correction factors used were those for the 950-foot height listed in Appendix A. The ground station readings were multiplied by a factor of 1.20 to correct for the absorption introduced by the steel blast shield. The factor 1.20 was determined experimentally by Project 2.5c by comparing dose rates from inside the steel shield of the ground station and from balloon instruments fastened to the ground stations on Shots Hood and Owens.

The rate measurements show that the ratio of free-air measurements to ground measurements remains constant over the first few seconds. The records cover the time during which the nitrogen-capture gamma radiation is received (a few msec to about a quarter of a second) and the first few seconds of the fission product gamma radiation. Since there is no difference in the relative gamma dose rates over this time interval, there is apparently no difference between the air-ground-interface effect on nitrogen-capture or fission-product gamma radiation. The ratio of free-air measurement to the ground measurement varied among the five records obtained. The average ratio was 1.35, which is about the same as the ratio obtained from total gamma dose measurements.

4.2.4 Reliability of Data. The measurements of total-gamma dose, gamma dose rate, and sulfur neutron flux are all believed to be reliable. The measurements of total gamma dose scatter considerably, but the uncertainty because of scatter is less than the magnitude of the increase in dose with height. Thus, the results are statistically valid. There is some uncertainty in the chemical neutron-rep-dose measurements, but it is felt that the measurements are reliable within 20 percent.

4.2.5 Accomplishment of Objectives. The objectives of this project, to measure the effect of the air-ground interface on total gamma dose, on neutron flux, and on gamma dose rate, have been achieved. The neutron measurements are not as definitive as desired.

4.2.6 Effectiveness of Instrumentation. All the instruments and dosimeters used in this study operated essentially as expected. Failures were caused either by errors in predictions

of expected dosage or by failure to have the instruments in place at shot time or by malfunctions of auxiliary equipment.

The balloon system operated considerably better than expected. The contract specifications required the balloon to carry 25 pounds of instruments and to be able to survive winds up to 25 knots. These requirements were believed to be rather severe for known types of aerodynamic-shaped balloons. In practice, the General Mills aerocap balloon carried 50 pounds of instruments and survived winds up to 40 knots. Unfortunately, local winds in excess of 40 knots were encountered with distressing frequency, particularly when shots were delayed because of weather. During the operation 11 balloons were lost because of excessive winds and one because of a helium leak. The balloons were not designed for deflation; so it was necessary to keep the balloons aloft during delays and, therefore, exposed to the local gusty winds during late afternoons.

Chapter 5
CONCLUSIONS and RECOMMENDATIONS

5.1 CONCLUSIONS

5.1.1 Total Gamma Dose. The total gamma dose increased with height above the ground up to an increase of 30 percent at about 400 feet. There was no further change in the total gamma dose up to 950 feet. There was no change in the effect of the air-ground interface on total gamma radiation with distance over the range of 1,500 to 3,500 yards from burst point and for yields up to 80 kt. The increase in total gamma dose with height was largely due to low-energy scattered radiation.

5.1.2 Neutron Measurements. Neutron flux measured with sulfur pellets increased with height above the ground up to an increase of 30 percent at about 500 feet. There was no further change in the sulfur neutron flux up to 950 feet. Any changes in neutron rep dose with heights up to 950 feet above the ground were probably less than 20 percent.

5.1.3 Gamma Rate Measurements. There was no change in the ratio of free-air dose rate measured at 950 feet compared to ground measurements during the first 5 seconds after burst.

5.2 RECOMMENDATIONS

Ground measurements of gamma radiation should be multiplied by a factor of 1.3 when used to make calculations of free-air gamma dosage. For dose predictions of aircraft crews exposed to initial gamma radiation, allowances should be made for shielding provided by the aircraft structure.

Appendix A
SUMMARY of RAW DATA

TABLE A.1 BALLOON POSITION AT SHOT TIME

Shot	Station	Location at Shot Time
	yd	ft
Lassen	No results, blue boxes did not trigger	
Wilson	1,500	16 south 332 west of Ground Station
	2,000	339 south 291 west of Ground Station
	2,500	Not in position, believed to be on ground
	3,040 (Assumed)	178 south 312 west of Ground Station
Hood	2,000	38 south 14 west of Ground Station
	2,500	41 south 28 west of Ground Station
	3,040	37 south 41 west of Ground Station
	3,580	37 south 23 west of Ground Station
Owens	No results, one camera plate fogged Balloons are assumed to be vertical since winds were calm	

TABLE A.2 STATION LOCATIONS

Shot	Shot Location Nevada State Grid	Station	Station Location Nevada State Grid	Horizontal Distance from Ground Zero
				yd
Boltzmann	N 854,124 E 687,540	Franklin Tower	N 837,026 E 688,416	5,704
Lassen Wilson Hood Owens	N 868,633 E 682,418	2.5c 9003.02	N 865,753 E 683,259	1,000
		2.5c 9003.03	N 864,313 E 683,680	1,500
		2.5c 9003.04	N 862,873 E 684,100	2,000
		2.5c 9003.05	N 861,433 E 684,520	2,500
		2.5c 9003.06	N 859,878 E 684,975	3,040
		2.5c 9003.07	N 858,323 E 685,368	3,580
Diablo	N 874,146 E 662,634	Whitney Tower	N 869,823 E 660,103	1,670
		Shasta Tower	N 866,030 E 663,322	2,715
Kepler	N 854,233 E 664,463	Shasta Tower	N 866,030 E 663,322	3,950

TABLE A.3 CORRECTION FACTORS FOR TOTAL GAMMA DOSE, AND FOR TOTAL NEUTRON MEASUREMENTS

Height	Slant Range	Average Relative Air Density, NACA	Slant Range Correction	Air Density Correction, Gamma, λ = 325 yd	Air Density Correction, Neutron, λ = 220 yd	Slant Range	Average Relative Air Density, NACA	Slant Range Correction	Air Density Correction, Gamma, λ = 325 yd	Air Density Correction, Neutron, λ = 220 yd
ft	yd					yd				
	Shot Boltzmann, Station Franklin Tower					Shot Wilson, Station 2.5c 9003.03				
0	5,711	0.8353	1.000	1.000	—	1,510	0.8519	1.000	1.000	1.000
3	5,711	0.8352	1.000	0.9983	—	1,510	0.8519	1.000	1.000	0.995
10	5,711	0.8348	1.000	0.9917	—	1,509	0.8519	0.9987	1.000	0.991
30	5,711	0.8342	1.000	0.9813	—	1,508	0.8512	0.9974	0.9943	0.982
50	5,711	0.8337	1.000	0.9727	—	1,506	0.8508	0.9947	0.9856	0.977
100	5,710	0.8322	0.9997	0.9482	—	1,503	0.8497	0.9908	0.9747	0.973
150	5,710	0.8308	0.9994	0.9255	—	1,500	0.8485	0.9868	0.9636	0.955
200	5,709	0.8295	0.9994	0.9047	—	1,497	0.8471	0.9829	0.9500	0.938
250	5,709	0.8283	0.9991	0.8864	—	1,494	0.8455	0.9789	0.9366	0.930
300	5,708	0.8272	0.9988	0.8691	—	1,492	0.8438	0.9763	0.9259	0.900
400	—	—	—	—	—	1,487	0.8399	0.9697	0.9044	0.872
500	—	—	—	—	—	1,484	0.8354	0.9658	0.8772	0.834
600	—	—	—	—	—	1,481	0.8319	0.9618	0.8575	0.814
700	—	—	—	—	—	1,478	0.8297	0.9579	0.8429	0.801
800	—	—	—	—	—	1,477	0.8276	0.9570	0.8334	0.786
900	—	—	—	—	—	1,476	0.8261	0.9557	0.8264	0.786
950	—	—	—	—	—	1,476	0.8256	0.9557	0.8264	0.778
	Shot Wilson, Station 2.5c 9003.04					Shot Wilson, Station 2.5c 9003.06				
0	2,008	0.8516	1.000	1.000	—	3,046	0.8512	1.000	1.000	—
3	2,008	0.8515	1.000	1.000	—	3,046	0.8512	1.000	1.000	—
10	2,009	0.8514	1.000	1.000	—	3,046	0.8509	1.000	0.9972	—
30	2,010	0.8510	1.002	1.003	—	3,046	0.8505	1.000	0.9943	—
50	2,012	0.8507	1.004	1.006	—	3,047	0.850[illegible]	1.001	0.9914	—
100	2,017	0.8496	1.009	1.012	—	3,048	0.8490	1.001	0.9858	—
150	2,022	0.8487	1.014	1.017	—	3,049	0.8476	1.002	0.9746	—
200	2,028	0.8471	1.020	1.023	—	3,051	0.8460	1.003	0.9663	—
250	2,033	0.8457	1.025	1.026	—	3,053	0.8444	1.005	0.9581	—
300	2,038	0.8441	1.030	1.029	—	3,054	0.8425	1.005	0.9445	—
400	2,050	0.8405	1.042	1.038	—	3,058	0.8380	1.008	0.9179	—
500	2,061	0.8363	1.054	1.041	—	3,062	0.8343	1.011	0.8971	—
600	2,073	0.8326	1.066	1.047	—	3,066	0.8310	1.013	0.8794	—
700	2,086	0.8304	1.079	1.065	—	3,071	0.8289	1.017	0.8744	—
800	2,099	0.8284	1.093	1.086	—	3,076	0.8271	1.020	0.8694	—
900	2,113	0.8268	1.107	1.112	—	3,081	0.8257	1.023	0.8694	—
950	2,120	0.8261	1.115	1.124	—	3,084	0.8252	1.025	0.8720	—

TABLE A.3 CONTINUED

Height	Slant Range	Average Relative Air Density, NACA	Slant Range Correction	Air Density Correction, Gamma, λ = 325 yd	Air Density Correction, Neutron λ = 220 yd	Slant Range	Average Relative Air Density, NACA	Slant Range Correction	Air Density Correction, Gamma, λ = 325 yd	Air Density Correction, Neutron, λ = 220 yd
ft	yd					yd				
	Shot Hood, Station 2.5c 9003.04					Shot Hood, Station 2.5c 9003.05				
0	2,065	0.8050	1.000	1.000	1.000	2,562	0.8048	1.000	1.000	—
3	2,063	0.8050	1.000	1.000	1.000	2,562	0.8047	1.000	1.000	—
10	2,062	0.8048	0.999	0.994	0.996	2,561	0.8045	0.999	0.994	—
30	2,061	0.8042	0.998	0.989	0.986	2,560	0.8040	0.999	0.989	—
50	2,060	0.8037	0.997	0.986	0.976	2,559	0.8035	0.998	0.983	—
100	2,056	0.8024	0.993	0.966	0.949	2,556	0.8022	0.995	0.965	—
150	2,053	0.8011	0.990	0.955	0.930	2,554	0.8008	0.994	0.953	—
200	2,050	0.7997	0.988	0.939	0.907	2,552	0.7995	0.992	0.939	—
250	2,047	0.7983	0.985	0.926	0.890	2,549	0.7981	0.990	0.923	—
300	2,044	0.7969	0.982	0.913	0.869	2,547	0.7966	0.988	0.910	—
400	2,039	0.7942	0.977	0.887	0.828	2,543	0.7939	0.985	0.884	—
500	2,034	0.7917	0.972	0.867	0.782	2,540	0.7914	0.983	0.863	—
600	2,030	0.7894	0.968	0.845	0.744	2,536	0.7892	0.980	0.840	—
700	2,027	0.7876	0.966	0.830	0.704	2,533	0.7874	0.978	0.824	—
800	2,024	0.7860	0.963	0.819	0.675	2,531	0.7858	0.976	0.812	—
900	2,021	0.7844	0.960	0.805	0.662	2,529	0.7842	0.974	0.798	—
950	2,020	0.7836	0.959	0.803	0.656	2,529	0.7834	0.974	0.794	—
	Shot Hood, Station 2.5c 9003.06					Shot Hood, Station 2.5c 9003.07				
0	3,083	0.8045	1.000	1.000	—	3,611	0.8044	1.000	1.000	—
3	3,083	0.8044	1.000	1.000	—	3,611	0.8044	1.000	1.000	—
10	3,083	0.8042	1.000	0.997	—	3,611	0.8041	1.000	0.997	—
30	3,082	0.8037	0.999	0.991	—	3,610	0.8036	0.999	0.989	—
50	3,081	0.8032	0.999	0.986	—	3,609	0.8031	0.999	0.980	—
100	3,079	0.8019	0.997	0.969	—	3,608	0.8018	0.999	0.966	—
150	3,076	0.8005	0.996	0.950	—	3,606	0.8004	0.997	0.947	—
200	3,074	0.7992	0.994	0.937	—	3,604	0.7991	0.996	0.931	—
250	3,072	0.7978	0.993	0.921	—	3,603	0.7977	0.995	0.915	—
300	3,071	0.7964	0.992	0.908	—	3,602	0.7963	0.995	0.900	—
400	3,067	0.7937	0.989	0.877	—	3,599	0.7936	0.993	0.869	—
500	3,064	0.7912	0.988	0.852	—	3,596	0.7911	0.992	0.867	—
600	3,062	0.7890	0.986	0.833	—	3,595	0.7889	0.991	0.821	—
700	3,059	0.7873	0.984	0.814	—	3,593	0.7872	0.990	0.803	—
800	3,057	0.7857	0.983	0.800	—	3,591	0.7856	0.989	0.787	—
900	3,055	0.7841	0.982	0.784	—	3,590	0.7840	0.989	0.773	—
950	3,054	0.7833	0.981	0.778	—	3,590	0.7832	0.989	0.767	—

TABLE A.3 CONTINUED

Height	Slant Range	Average Relative Air Density, NACA	Slant Range Correction	Air Density Correction, Gamma, λ = 325 yd	Air Density Correction, Neutron, λ = 220 yd	Slant Range	Average Relative Air Density, NACA	Slant Range Correction	Air Density Correction, Gamma, λ = 325 yd	Air Density Correction, Neutron, λ = 220 yd
ft	yd					yd				
	Shot Diablo, Station Whitney Tower					Shot Diablo, Station Shasta Tower				
3	1,679	0.8189	1.000	1.000	—	2,714	0.8206	1.000	1.000	—
25	1,678	0.8186	0.999	0.997	—	2,714	0.8203	1.000	0.997	—
50	1,677	0.8182	0.998	0.991	—	2,713	0.8199	0.999	0.991	—
100	1,676	0.8173	0.997	0.986	—	2,712	0.8191	0.999	0.983	—
150	1,674	0.8165	0.994	0.977	—	2,711	0.8182	0.998	0.975	—
200	1,673	0.8156	0.993	0.969	—	2,710	0.8174	0.997	0.966	—
250	1,672	0.8147	0.992	0.964	—	2,710	0.8166	0.997	0.961	—
300	1,671	0.8138	0.990	0.958	—	2,709	0.8157	0.996	0.953	—
350	1,671	0.8129	0.990	0.953	—	2,708	0.8148	0.996	0.942	—
400	1,670	0.8121	0.989	0.947	—	2,708	0.8139	0.996	0.936	—
450	1,670	0.8114	0.989	0.945	—	2,708	0.8130	0.996	0.931	—
500	1,670	0.8106	0.989	0.942	—	2,707	0.8122	0.995	0.923	—
	Shot Owens, Station 2.5c 9003.03					Shot Owens, Station 2.5c, 9003.04				
0	1,510	0.8244	1.000	1.000	—	2,008	0.8241	1.000	1.000	—
3	1,510	0.8243	0.999	1.000	—	2,008	0.8240	1.000	1.000	—
10	1,509	0.8241	0.999	0.997	—	2,007	0.8239	0.999	0.997	—
30	1,509	0.8236	0.997	0.994	—	2,007	0.8234	0.999	0.994	—
50	1,508	0.8231	0.995	0.989	—	2,006	0.8229	0.998	0.989	—
100	1,506	0.8221	0.993	0.980	—	2,005	0.8220	0.997	0.980	—
150	1,505	0.8213	0.992	0.975	—	2,004	0.8212	0.996	0.975	—
200	1,504	0.8206	0.991	0.969	—	2,003	0.8206	0.995	0.969	—
250	1,503	0.8201	0.990	0.966	—	2,002	0.8200	0.994	0.964	—
300	1,502	0.8195	0.988	0.961	—	2,001	0.8194	0.993	0.958	—
400	1,501	0.8182	0.987	0.953	—	2,001	0.8181	0.993	0.950	—
500	1,500	0.8170	0.988	0.947	—	2,000	0.8169	0.992	0.942	—
600	1,501	0.8156	0.990	0.942	—	2,000	0.8155	0.992	0.934	—
700	1,502	0.8141	0.991	0.939	—	2,001	0.8140	0.993	0.929	—
800	1,503	0.8126	0.995	0.934	—	2,002	0.8125	0.994	0.923	—
900	1,506	0.8112	0.995	0.936	—	2,004	0.8111	0.996	0.918	—
950	1,507	0.8105	0.996	0.934	—	2,005	0.8104	0.997	0.918	—

TABLE A.3 CONTINUED

Height	Slant Range	Average Relative Air Density, NACA	Slant Range Correction	Air Density Correction, Gamma, λ = 325 yd	Air Density Correction, Neutron, λ = 220 yd	Slant Range	Average Relative Air Density, NACA	Slant Range Correction	Air Density Correction, Gamma, λ = 325 yd	Air Density Correction, Neutron, λ = 220 yd
ft	yd					yd				
	Shot Owens, Station 2.5c 9003.05					Shot Owens, Station 2.5c 9003.06				
0	2,506	0.8239	1.000	1.000	—	3,046	0.8236	1.000	1.000	—
3	2,506	0.8238	1.000	0.997	—	3,045	0.8235	0.999	0.997	—
10	2,506	0.8236	1.000	0.997	—	3,045	0.8234	0.999	0.994	—
30	2,506	0.8231	1.000	0.994	—	3,045	0.8229	0.999	0.991	—
50	2,505	0.8227	0.999	0.989	—	3,045	0.8225	0.999	0.988	—
100	2,504	0.8218	0.998	0.980	—	3,044	0.8217	0.999	0.977	—
150	2,503	0.8211	0.998	0.972	—	3,043	0.8209	0.998	0.969	—
200	2,503	0.8205	0.998	0.969	—	3,042	0.8203	0.997	0.961	—
250	2,502	0.8199	0.997	0.961	—	3,042	0.8197	0.997	0.958	—
300	2,501	0.8193	0.996	0.955	—	3,041	0.8191	0.997	0.949	—
400	2,501	0.8180	0.996	0.947	—	3,041	0.8179	0.997	0.939	—
500	2,500	0.8167	0.995	0.936	—	3,040	0.8166	0.996	0.926	—
600	2,500	0.8153	0.995	0.926	—	3,040	0.8152	0.996	0.915	—
700	2,501	0.8139	0.996	0.920	—	3,041	0.8137	0.997	0.905	—
800	2,502	0.8123	0.997	0.910	—	3,042	0.8122	0.997	0.897	—
900	2,503	0.8109	0.998	0.905	—	3,043	0.8108	0.998	0.887	—
950	2,504	0.8102	0.998	0.902	—	3,043	0.8101	0.998	0.882	—

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TABLE A.4 BASIC DATA, RADIATION DOSAGE VERSUS ALTITUDE

Height	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading
ft	r	r		r	r		r	r	
	Shot Boltzman, Station Franklin Tower, NBS Dosimeter			Shot Boltzman, Station Franklin Tower, LSD Dosimeter			Shot Boltzman, Station Franklin Tower, Unshielded Film Dosimeter		
Ground	—	0.09	1.000	—	0.060	1.000	—	0.115	1.000
1	0.10	0.10	1.111	0.054	0.054	0.870	0.10	0.10	0.870
3	0.08	0.08	0.899	0.066	0.066	1.130	0.13	0.13	1.130
10*	0.12	0.12	1.333*	0.078	0.077	2.417*	0.28	0.278	2.417*
30*	0.16	0.16	1.744*	0.110	0.108	2.817*	0.33	0.324	2.817*
50	0.10	0.097	1.078	0.078	0.076	1.096	0.13	0.126	1.096
100	0.10	0.095	1.056	0.078	0.074	1.235	0.15	0.142	1.235
150	0.10	0.092	1.022	0.096	0.089	2.409	0.30	0.277	2.409
200	0.09	0.081	0.900	0.072	0.065	1.026	0.13	0.118	1.026
250	0.085	0.075	0.833	0.072	0.064	0.774	0.10	0.089	0.774
300	0.074	0.064	0.711	0.060	0.052	0.757	0.10	0.087	0.754
	Shot Wilson, Station 1,500 yards, DT 60 Dosimeter			Shot Wilson, Station 1,500 yards, Chemical Gamma Dosimeter			Shot Wilson, Station 1,500 yards, Quartz Fiber Dosimeter		
Ground	—	447	1.000	—	350	1.000	—	235	1.000
0	422	422	0.946	310	310	0.886	—	—	—
3	451	451	1.011	310	310	0.886	—	—	—
10	467	466	1.045	430	429	1.226	—	—	—
30	464	460	1.031	335	332	0.949	—	—	—
50	448	439	0.984	335	328	0.937	240	235	1.000
100	469	453	1.016	335	324	0.926	250	241	1.026
150	497	472	1.058	430	409	1.169	600	—	—
200	488	456	1.022	430	402	1.149	—	—	—
250	532	487	1.092	305	280	0.800	—	—	—
300	541	489	1.096	470	425	1.214	—	—	—
400	586	514	1.152	430	465	1.328	—	—	—
500	626	530	1.188	430	364	1.040	—	—	—
600	602	496	1.112	430	355	1.014	—	—	—
700	601	485	1.087	470	379	1.085	263	212	0.902
800	635	506	1.135	470	375	1.071	290	231	0.983
900	652	515	1.155	470	371	1.060	320	253	1.077
950	608	480	1.076	470	371	1.060	240	268	1.140

* Dosimeter packages at 10 feet and 30 feet were suspended on cords between tower cross members; all other packages were taped to main structural members.

TABLE A.4 CONTINUED

Height	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading
ft	r	r		r	r		r	r	
	Shot Wilson, Station 2,000 yards, DT-60 Dosimeter			Shot Wilson, Station 2,000 yards Unshielded Film Dosimeter			Shot Wilson, Station 2,000 yards Quartz Fiber Dosimeter		
Ground	—	57.5	1.000	—	50	1.000	—	44.3	1.00
0	59.5	59.5	1.035	52	52	1.051	37.4	37.4	0.844
3	57	57	0.991	46	46	0.929	36.6	36.6	0.826
10	56	56	0.974	51	51	1.020	59	59	1.33
30	62	62	1.078	57	57	1.152	40	40.1	0.905
50	75	76	1.322	48	48	0.970	37.3	37.4	0.844
100	60.5	62	1.078	57	58	1.132	38.35	38.6	0.871
150	64	65	1.130	58	59	1.192	39	39.9	0.901
200	65	68	1.183	59	62	1.253	—	—	—
250	62	65	1.130	66	69	1.394	37.15	38.7	0.874
300	62	66	1.148	62	66	1.333	—	—	—
400	62	67	1.165	68	74	1.495	41.95	44	0.993
500	58	64	1.113	68	75	1.515	35.7	37.8	0.853
600	59	66	1.148	63	70	1.414	41.35	44.3	1.00
700	55.5	64	1.110	110	126	2.545	40.0	43.8	0.989
800	61.5	73	1.270	64	76	1.535	—	—	—
900	57	70	1.217	69	85	1.717	36.45	42.4	0.957
950	54.5	68	1.183	70	88	1.778	39	45.8	1.03
	Shot Wilson, Station 3,040 yards, LSD Dosimeter			Shot Hood, Station 2,000 yards, DT 60 Dosimeter			Shot Hood, Station 2,000 yards, Glass Needle Dosimeter		
Ground	—	3.31	1.000	—	730	—	—	545	1.000
0	3.25	3.25	0.982	745	745	1.020	519	519	0.952
3	3.40	3.40	1.027	714.5	715	0.978	555	555	1.018
10	3.28	3.27	0.988	—	—	—	564	560	1.027
30	3.45	3.43	1.036	769.5	759	1.040	462	456	0.837
50	3.43	3.40	1.027	747.5	735	1.007	581	571	1.048
100	3.75	3.70	1.118	—	—	—	—	—	—
150	3.65	3.56	1.076	700.5	663	0.872	515	487	0.894
200	3.80	3.68	1.112	838.5	778	1.068	555	515	0.945
250	3.95	3.80	1.148	698.5	637	0.874	599	546	1.002
300	3.98	3.78	1.142	837	750	1.028	564	505	0.927
400	3.98	3.68	1.112	959	831	1.138	564	489	0.897
500	4.01	3.64	1.200	—	—	—	—	—	—
600	4.07	3.62	1.094	130	842	1.151	608	497	0.912
700	3.94	3.50	1.057	—	—	—	—	—	—
800	4.20	3.72	1.142	1,158	913	1.251	634	499	0.916
900	4.16	3.70	1.118	1,177	909	1.243	705	545	1.000
950	3.91	3.50	1.057	1,180	908	1.241	731	562	1.031

TABLE A.4 CONTINUED

Height	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading
ft	r	r		r	r		r	r	
	Shot Hood, Station 2,000 yards, Chemical Gamma Dosimeter			Shot Hood, Station 2,500 yards, DT 60 Dosimeter			Shot Hood, Station 2,500 yards Unshielded Film Dosimeter		
Ground	—	408	1.000	—	105	1.000	—	101	1.000
0	475	475	1.160	107	107	1.015	100	100	0.987
3	350	350	0.858	102	102	0.972	98	98	0.967
10	400	39[illegible]	0.977	107	106	1.013	107	106	1.046
30	450	445	1.09	143	141	1.344	110	109	1.076
50	440	432	1.06	—	—	—	—	—	—
100	495	477	1.17	110	106	1.010	120	115	1.135
150	495	469	1.15	121	115	1.096	123	116	1.145
200	495	461	1.13	119	111	1.058	133	124	1.124
250	495	455	1.12	133	121	1.153	—	—	—
300	460	416	1.02	137	123	1.172	153	138	1.362
400	—	—	—	119	104	0.991	143	125	1.234
500	—	—	—	131	111	1.058	160	136	1.343
600	470	380	0.933	132	109	1.039	165	136	1.343
700	—	—	—	133	107	1.020	170	137	1.352
800	475	359	0.881	182	144	1.372	—	—	—
900	475	354	0.886	185	144	1.372	190	147	1.451
950	475	351	0.861	149	115	1.096	182	141	1.392
	Shot Hood, Station 2,500 yards, Glass Needle Dosimeter			Shot Hood, Station 2,500 yards, Quartz Fiber Dosimeter			Shot Hood, Station 3,040 yards Unshielded Film Dosimeter		
Ground	—	114	1.000	—	58	1.000	—	21.1	1.000
0	117	117	1.028	59	59	1.019	20.4	20.4	0.967
3	117	117	1.028	54	54	0.933	21.3	21.3	1.009
10	108	107	0.943	61	61	1.047	21.8	21.7	1.028
30	112	111	0.976	—	—	—	22.6	22.4	1.062
50	—	—	—	63	62	1.066	23	22.6	1.071
100	104	99	0.876	66	63	1.095	26.2	25.3	1.199
150	112	106	0.934	—	—	—	26	24.6	1.166
200	112	105	0.925	70	65	1.126	27.4	25.5	1.208
250	152	138	1.216	70	64	1.104	28.9	26.4	1.251
300	112	101	0.900	—	—	—	29.8	26.8	1.270
400	121	105	0.925	76	66	1.143	31.3	27.2	1.289
500	126	107	0.943	74	63	1.083	33.3	28	1.327
600	130	107	0.943	—	—	—	35.3	29	1.374
700	112	90	0.796	88	71	1.223	36	28.8	1.365
800	—	—	—	105	83	1.437	37.3	29.3	1.389
900	139	108	0.952	76	59	1.021	37.6	29.0	1.374
950	165	128	1.128	84	65	1.123	37.4	28.6	1.355

TABLE A.4 CONTINUED

Height	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading
ft	r	r		r	r		r	r	
	Shot Hood, Station 3,040 yards, Quartz Fiber Dosimeter			Shot Hood, Station 3,580 yards, Unshielded Film Dosimeter			Shot Hood, Station 3,580 yards, LSD Dosimeter		
Ground	—	14.6	1.000	—	5.4	1.000	—	7.2	1.000
0	14.9	14.9	1.021	5.5	5.5	1.018	7.0	7.0	0.972
3	14.4	14.4	0.986	5.5	5.5	1.018	7.2	7.2	1.000
10	14.4	14.4	0.986	5.1	5.1	0.944	7.5	7.5	1.042
30	14	13.9	0.952	5.4	5.3	0.981	7.9	7.8	1.083
50	15.6	15.4	1.055	5.8	5.7	1.055	7.9	7.7	1.069
100	12.5	12.1	0.829	6.6	6.4	1.185	7.9	7.7	1.069
150	16.7	15.8	1.082	6.0	5.7	1.055	8.3	7.8	1.083
200	17	15.8	1.082	7.0	6.5	1.204	8.4	6.0	0.833
250	17	15.5	1.062	7.1	6.5	1.204	8.5	7.7	1.069
300	15.9	14.3	0.979	7.4	6.6	1.222	8.6	7.6	1.055
400	18.5	16.1	1.103	8.0	6.9	1.278	9.2	7.9	1.097
500	17.1	14.4	0.986	7.8	6.7	1.241	8.5	7.3	1.014
600	20	16.4	1.123	8.1	6.6	1.222	9.0	7.4	1.028
700	17.9	14.3	0.979	8.8	7.0	1.296	9.4	7.5	1.042
800	25	19.7	1.349	9.1	7.1	1.315	9.2	7.2	1.000
900	19.1	14.7	1.007	8.8	6.7	1.241	9.7	7.4	1.028
950	19.5	14.9	1.021	9.4	7.1	1.315	8.8	6.7	0.930
	Shot Diablo, Station Shasta Tower, NBS Dosimeter			Shot Diablo, Station Shasta Tower, Quartz Fiber Dosimeter			Shot Diablo, Station Whitney Tower, Chemical Gamma Dosimeter		
Ground	—	1.88	1.000	—	2.1	1.000	—	64	1.000
0	1.85	1.85	0.984	2.2	2.2	1.048	64	64	1.000
3	1.91	1.91	1.016	2.0	2.0	0.952	64	64	1.000
25	2.07	2.06	1.096	1.9	1.9	0.905	61	61	0.950
50	2.28	2.25	1.199	2.0	2.0	0.952	69	68	1.066
100	2.35	2.31	1.229	2.0	2.0	0.933	61	60	0.936
150	2.38	2.31	1.229	2.1	2.0	0.971	66	64	1.002
200	2.38	2.29	1.218	2.0	1.9	0.919	80	77	1.203
250	2.45	2.35	1.250	3.5	3.4	1.595	60	57	0.895
300	2.55	2.42	1.287	2.6	2.5	1.176	71	67	1.053
350	2.65	2.48	1.319	2.1	2.0	0.938	71	67	1.047
400	2.55	2.38	1.266	2.8	2.6	1.243	73	68	1.069
450	2.63	2.43	1.293	2.9	2.7	1.281	—	—	—
500	2.93	1.77	0.942	1.9	1.7	0.829	82	76	1.194

TABLE A.4 CONTINUED

Height	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading
ft	r	r		r	r		r	r	
	Shot Diablo, Station Whitney Tower, Quartz Fiber Dosimeter			Shot Diablo, Station Whitney Tower, NBS Dosimeter			Shot Diablo, Station Whitney Tower, DT 60 Dosimeter		
Ground	—	82.5	1.000	—	79	1.000	—	95	1.000
0	85	85	1.030	77	77	0.965	95	95	1.000
3	80	80	0.970	82	82	1.035	—	—	—
25	100	100	1.207	74	74	0.930	116	115	1.211
50	62	61	0.743	82	81	1.023	113	112	1.177
100	100	98	1.190	84	83	1.041	99	97	1.024
150	100	97	1.178	91	88	1.115	118	115	1.206
200	133	128	1.552	98	94	1.190	106	102	1.068
250	105	100	1.216	92	88	1.109	121	116	1.217
300	100	95	1.150	100	95	1.197	104	98	1.034
350	110	104	1.258	98	92	1.166	150	141	1.484
400	115	108	1.307	95	89	1.123	137	128	1.352
450	85	79	0.962	102	95	1.203	121	113	1.185
500	70	65	0.790	99	92	1.165	146	136	1.432
	Shot Owens, Station 1,500 yards, Glass Needle Dosimeter			Shot Owens, Station 1,500 yards, DT 60 Dosimeter			Shot Owens, Station 1,500 yards, Unshielded Film Dosimeter		
Ground	—	519	1.000	—	894	1.000	—	504	1.000
0	—	—	—	—	—	—	—	—	—
3	519	519	1.000	869	869	0.972	510	510	1.012
10	—	—	—	923	919	1.028	500	498	0.988
30	543	539	1.038	1,020	1,013	1.134	550	546	1.084
50	546	539	1.038	980	966	1.081	505	498	0.988
100	597	582	1.121	1,034	1,008	1.128	800	780	1.548
150	597	578	1.115	—	—	—	790	765	1.518
200	622	598	1.155	—	—	—	940	904	1.793
250	—	—	—	—	—	—	—	—	—
300	—	—	—	—	—	—	890	846	1.679
400	630	592	1.140	—	—	—	1,000	941	1.868
500	—	—	—	1,234	1,153	1.290	1,400	1,308	2.597
600	780	726	1.400	—	—	—	1,080	1,005	1.994
700	—	—	—	—	—	—	880	818	1.622
800	—	—	—	—	—	—	1,130	1,045	2.074
900	805	750	1.445	—	—	—	1,150	1,071	2.126
950	793	738	1.425	1,601	1,489	1.666	—	—	—

TABLE A.4 CONTINUED

Height	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading
ft	r	r		r	r		r	r	
	Shot Owens, Station 2,000 yards, Unshielded Film Dosimeter			Shot Owens, Station 2,000 yards, DT 60 Dosimeter			Shot Owens, Station 2,000 yards, Quartz Fiber Dosimeter		
Ground	—	81.7	1.000	—	145	1.000	—	46	1.000
0	—	—	—	—	—	—	—	—	—
3	94	94	1.151	—	—	—	42	42	0.917
10	70	70	0.853	146	145	1.000	50	50	1.087
30	82	82	0.998	—	—	—	46	46	0.998
50	94	93	1.135	100	99	0.6788	—	—	—
100	82	80	0.980	132	129	0.8838	53	52	1.131
150	105	102	1.247	—	—	—	54	52	1.144
200	112	108	1.322	—	—	—	60	58	1.264
250	125	120	1.465	—	—	—	57	55	1.192
300	130	124	1.514	—	—	—	55	52	1.142
400	138	130	1.594	—	—	—	—	—	—
500	118	110	1.350	218	203	1.398	62	58	1.264
600	—	—	—	—	—	—	—	—	—
700	66	61	0.745	—	—	—	68	63	1.369
800	157	144	1.764	—	—	—	68	62	1.362
900	168	154	1.880	—	—	—	—	—	—
950	150	137	1.681	211	193	1.325	—	—	—
	Shot Owens, Station 2,500 yards, Unshielded Film Dosimeter			Shot Owens, Station 2,500 yards, Quartz Fiber Dosimeter			Shot Owens, Station 2,500 yards, LSD Dosimeter		
Ground	—	12.7	1.000	—	10	1.000	—	16.5	1.000
0	13	13	1.024	—	—	—	16.5	16.5	1.000
3	12	12	0.921	10	10	0.960	—	—	—
10	14	14	1.063	10	10	1.040	—	—	—
30	13	13	1.031	10	10	0.970	19.2	19.1	1.158
50	16	15	1.205	10	10	0.990	16.9	16.7	1.012
100	16	16	1.236	11	10	1.030	18.6	18.2	1.103
150	16	15	1.181	12	11	1.120	21.5	20.8	1.261
200	18	17	1.370	12	11	1.110	21.5	20.8	1.261
250	17	16	1.260	—	—	—	22.8	21.8	1.321
300	20	19	1.520	12	11	1.140	22.5	21.4	1.297
400	19	18	1.409	—	—	—	—	—	—
500	29	27	2.102	12	11	1.120	18.2	17.0	1.030
600	20	18	1.449	—	—	—	24.8	22.8	1.382
700	21	19	1.520	15	14	1.360	24.7	22.6	1.370
800	26	24	1.858	14	13	1.270	—	—	—
900	23	21	1.638	—	—	—	28.3	25.6	1.552
950	22	20	1.559	16	14	1.400	25.0	22.5	1.364

TABLE A.4 CONTINUED

Height	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading	Reading	Corrected Reading	Ratio: Corrected Reading to Ground Reading
ft	r	r		r	r		r	r	
	Shot Owens, Station 3,040 yards, Unshielded Film Dosimeter			Shot Owens, Station 3,040 yards, LSD Dosimeter			Shot Owens, Station 3,040 yards, NBS Dosimeter		
Ground	—	3.02	1.000	—	4.99	1.000	—	2.19	1.000
0	2.8	2.80	0.927	5.80	5.80	1.162	—	—	—
3	2.8	2.79	0.924	—	—	—	2.2	2.19	1.000
10	3.5	3.48	1.152	4.20	4.17	0.836	—	—	—
30	2.8	2.77	0.917	4.90	4.86	0.974	—	—	—
50	2.95	2.91	0.964	4.85	4.79	0.960	—	—	—
100	3.20	3.12	1.033	5.28	5.15	1.032	—	—	—
150	3.30	3.19	1.056	4.95	4.79	0.960	—	—	—
200	3.40	3.26	1.079	5.60	5.37	1.076	—	—	—
250	3.40	3.25	1.076	5.80	5.54	1.110	—	—	—
300	3.40	3.22	1.066	—	—	—	—	—	—
400	4.20	3.93	1.301	6.10	5.71	1.144	—	—	—
500	4.35	4.01	1.328	6.45	5.95	1.192	2.8	2.58	1.178
600	4.45	4.06	1.344	5.80	5.29	1.060	—	—	—
700	5.10	4.60	1.523	6.50	5.86	1.174	—	—	—
800	5.10	4.56	1.510	6.10	5.46	1.094	—	—	—
900	5.40	4.78	1.583	7.00	6.20	1.242	—	—	—
950	4.90	—	1.427	6.50	5.72	1.146	3.0	2.64	1.205

Appendix B
AEROCAP BALLOON OPERATION

Balloons used were General Mills aerocaps, approximately 31 feet long and 11 feet in diameter (Figures B.1 and B.2). The balloon fabric was 3-mil polyethylene plastic. The aerocaps (aerodynamic captive balloons) were shaped like miniature barrage balloons or blimps. The three tail fins were inflated plastic. The pressure from a small battery-driven centrifugal pump kept the fins pressurized to shape. In order to maintain the aerodynamic shape of the balloon, it was essential that the skin be kept taut at all times. This was accomplished by means of an inner air-tight bag or ballonett. The ballonett was partially filled with air, which was kept at constant pressure by a centrifugal pump similar to the one on the tail fins. When the helium pressure dropped because of decreased temperature or a slow leak, the centrifugal pump forced air into the ballonett. The ballonett expanded to maintain the pressure in the main balloon compartment. When the helium pressure increased because of increasing temperature, air was driven out of the ballonett through the centrifugal pump by the helium pressure. The volume of the ballonett was 648 ft^3. The volume of the balloon proper was 3,320 ft^3.

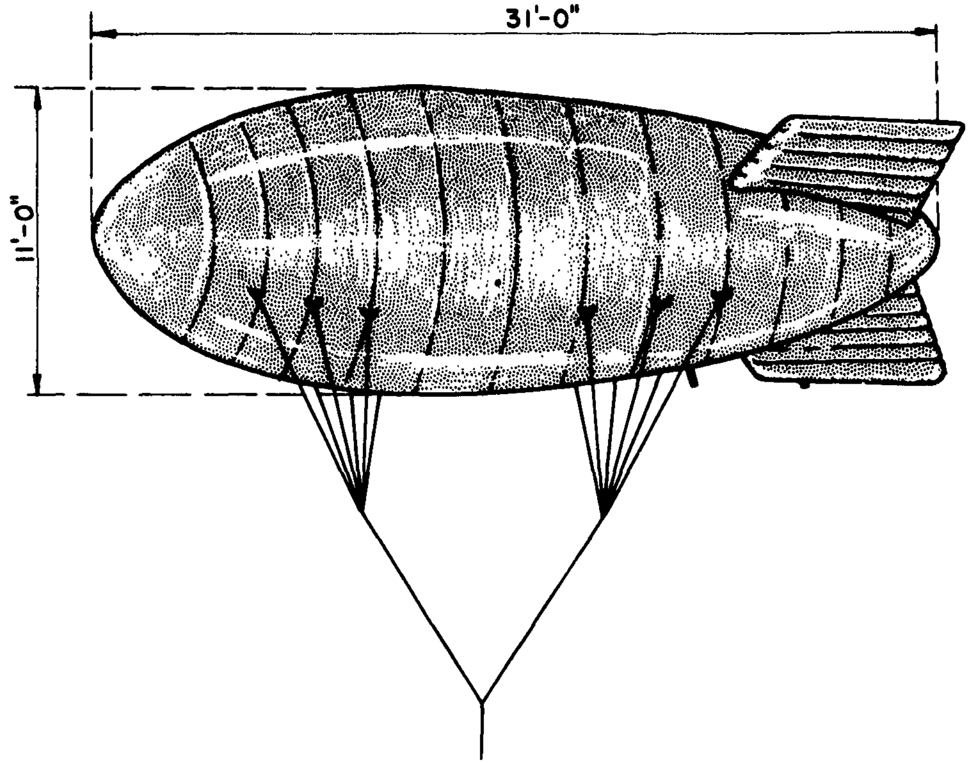
The balloon was held on each side by a set of four nylon lines taped to the forward section and three nylon lines taped to the rear section. The forward lines terminated at load rings about 4 feet below the body of the balloon. Bridle lines, each 14 feet long, led from the front and rear load rings to a single suspension point. A load bar to carry instruments and to serve as an attachment point for the mooring cable was attached to the suspension point. The balloon was tethered by a single mooring cable, and in operation the balloon combined the characteristics of a balloon and a kite. With no wind, the only lift was provided by the buoyancy of the helium. As the wind increased, the aerodynamic lift increased approximately as the square of the wind velocity. This helped to keep the balloon nearly vertical, despite the horizontal wind drag. At approximately 40 knots, the aerodynamic lift was sufficient to break the mooring cable, which was a 3/32-inch stainless-steel aircraft cable with a breaking strength of 1,200 pounds. With no wind, the gross lift was about 150 pounds. Weight of the balloon with motors and batteries was 60 pounds. Weight of the bridle and mooring cable was 20 pounds. This left 70 pounds net lift. The actual instrument loads varied between stations but were about 50 pounds.

The balloons were inflated at a launching pad 950 feet from the ground anchors. The ground anchors were auger-type anchors with 6-inch-diameter blades set 4 feet in the ground. Two anchors were used at each station. The mooring cable was fastened to the ground anchors and laid out to the launching pad. The coaxial signal cable and a 1/16-inch steel sash-cord cable were laid out beside the mooring cable. The coaxial cable was taped to the sash cord every 5 feet. Total dosimeter packages were fastened to the sash cord at intervals to give the desired spacing of dosimeters above the ground. The packages were fastened with masking tape and wire. The purpose of the sash cord was to carry the weight of the dosimeter packages and to provide support for the coaxial cable.

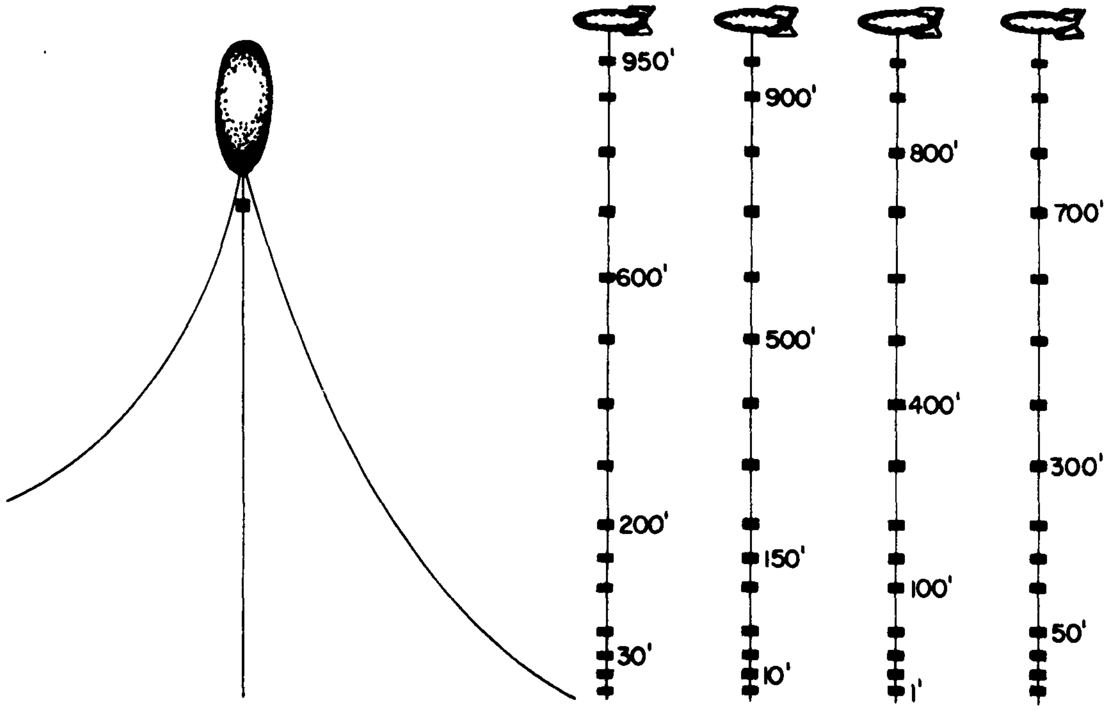
The mooring cable was passed through a pulley attached to the bumper of a weapons carrier and fastened to the balloon suspension point. The balloon, meanwhile, was held by temporary tiedowns fastened to the load rings. For launching, the temporary tiedowns were removed and the balloon eased upward by hand until the balloon was held by the mooring cable. The sash cord and the gamma-rate instrument box were fastened to the load bar. The coaxial cable was connected to the rate instrument. To raise the balloon aloft, the weapons carrier was driven toward the ground anchors. The balloon could be lowered simply by driving in the opposite direction. Plastic clothespins spaced at 15-foot intervals were used to fasten the sash cord to the mooring cable. This prevented the cables from tangling and chafing the coaxial cable. Clothespins were used since they were a readily available snap fastener and provided a method of quick attachment during launching and quick detachment when the balloons were lowered to change batteries.

After shot delays, the balloons were lowered and the instruments removed. The balloons were then tethered at a height of about 100 feet with double bridles and four mooring cables. This increased strength of cable was used to insure the balloons would not break the mooring cable because of wind loading. A height of 100 feet was chosen since it was high enough to keep the balloons clear of the ground and low enough to permit easy visual inspection.

As a safety measure to prevent the balloons escaping with instruments attached, a tension switch was placed above the load bar. This switch fired detonators in the top of the balloon when the mooring cable tension reached 800 pounds. The switch and detona-



B.1 General Mills aerocap balloon.



B.2 Schematic of balloon instrumentation.

tors operated satisfactorily, but on several occasions the balloons still broke the mooring cables. This was believed to be caused by a sharp increase in wind velocity that increased the load to 800 pounds and then to over 1,200 pounds before the helium could escape. Stronger mooring cables could not be used without decreasing the instrument load, since there was no available excess lift under zero wind conditions. Under good conditions there were 20 pounds of excess lift but this vanished with any slight helium leak.

The method finally adopted was to replace the tension switch with a short link of 1,000-pound test cable. When the tension, because of wind loading exceeded 1,000 pounds, the link broke, letting the balloon free. The balloon ascended rapidly for 3,000 or 4,000 feet until the expanding helium ruptured the fabric. All the balloons lost in this manner were found about 10 miles downwind from the point of breakaway. No instruments were lost, since they were all below the weak link.

The balloons were filled from U. S. Navy helium trailers. A 100-foot high-pressure hose ran from the truck to a metal diffuser nozzle. The diffuser was a perforated steel pipe 3 feet long and 2 inches in diameter. The filling tube on the balloons was a 5-inch-diameter plastic tube attached to the tail section.

REFERENCES

1. Ross G. Larrick and others; "Gamma Exposure versus Distance"; Project 2.1, Operation Teapot, ITR-1115, May 1955; Evans Signal Laboratory, Belmar, New Jersey; Confidential Formerly Restricted Data.

2. T.D. Hanscome and D.K. Willett; "Neutron Flux Measurements"; Project 2.2, Operation Teapot, ITR-1116, May 1955; U.S. Naval Radioligical Defense Laboratory, Washington, D.C.; Secret Restricted Data.

3. "Capabilities of Atomic Weapons"; TM 23-200, November 1957; Armed Forces Special Weapons Project, Washington, D. C.; Secret Restricted Data.

4. E.N. York; "Initial Nuclear Radiation from Low Yield Fission Weapons"; AFSWC TN 56-14, April 1956; Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico; Secret Restricted Data.

5. Frank W. Titus and Martin J. Berger; "Preliminary Results of Propagation of Gamma Radiation Near a Boundary"; Memorandum, 11 June 1956, U.S. Department of Commerce, National Bureau of Standards; Unclassified.

6. Herbert Goldstein and Ernest J. Wilkins, Jr.; "Calculations of the Penetration of Gamma Rays"; NYO 3075, 30 June 1954; New York Cperations Cffice of the Atomic Energy Commission, New York, New York; Unclassified.

7. M. Ehrlich; "Photographic Dosimetry of X and Gamma Rays"; Handbook 57, August 1954; U.S. Department of Commerce, National Bureau of Standards; Unclassified.

8. James H. Schulman; "Glass Dosimeters for Radiation Measurements"; TID-8006, March 1956; Unclassified.

9. George V. Taplin and others; "Measurement of Initial and Residual Radiations by Chemical Methods"; Project 39.6, Operation Teapot, ITR-1171, May 1955, School of Medicine, University of California at Los Angeles; Secret Restricted Data.

10. David L. Rigotti; "Neutron Flux From Selected Nuclear Devices"; Project 2.3, Operation Plumbbob, ITR-1412, August 1957; Chemical Warfare Laboratories, Army Chemical Center, Maryland; Secret Restricted Data.

11. R.S. Hart and J.P. Hale, Jr.; "Fast Neutron Monitoring with NTA Film Packets"; NAA-SR-1536, July 15, 1956; Unclassified.

12. Gerald Carp and others; "Initial Gamma Radiation Intensity and Neutron Induced Gamma Radiation of NTS Soil"; Project 2.5, Operation Plumbbob, ITR-1414, November 1957, U.S. Army Signal Engineering Laboratories, Fort Monmouth, New Jersey; Secret Restricted Data.

13. Eric T. Clark and others; "Scattering of Gamma Rays Near an Interface"; AFSWC TR 57-3, June 1957; Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico; Unclassified.